Meteorological Office

Annual Report 1979

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METEOROLOGICAL OFFICE
1979

Presented by the Director-General
to the
Secretary of State for Defence

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Cover photograph: Shinfield Park in winter. Photograph taken by Mr T. R. Spalding, Meteorological Office College.

FOREWORD BY THE DIRECTOR-GENERAL

The Office was honoured by a visit on 15 June from His Royal Highness The Prince of Wales who showed a keen interest in the work of the Central Forecasting Office and the Computing Laboratory. Later in the day His Royal Highness opened the European Centre for Medium Range Weather Forecasts at Shinfield Park, Reading, in a ceremony attended by Ministers or Ambassadors of all 17 participating countries and the Directors of their Meteorological Services. The Centre became operational during the year and now issues forecasts for up to seven days ahead each day. These are transmitted to the national meteorological services of the member states for evaluation and for use as they judge appropriate. Although the numerical model used by the Centre differs in several respects from the Meteorological Office model, the overall accuracy of forecasts up to six days ahead produced by the two models is very similar and encouraging, but improved models and input data will almost certainly be required to produce useful longer-range forecasts.

In a year with a severe winter, the Office was busier than ever and was often hard-pressed to meet all the demands for its services. The number of direct enquiries to forecasting offices reached a new record of 2.19 million whilst 2.32 million forecasts were made for civil and military aviation, and the number of calls on the Automatic Telephone Weather Service jumped again by 25 per cent to 30.8 million.

Much effort is being devoted to the development of new and improved numerical forecasting models for use on the new computer due to be delivered early in 1981. The 10-level model covering most of the northern hemisphere will be replaced by a 15-level model stretching to at least 20°S and capable of covering the whole globe if required. Additional levels near the ground should permit better representation of boundary-layer processes and additional levels near the tropopause should result in improved forecasts of the jet streams. The horizontal grid length will also be reduced and improvements made in the representation of sub-grid-scale processes. Corresponding improvements will be made in the fine-mesh models used for quantitative forecasts of precipitation over the British Isles and western Europe.

The Short Period Weather Forecasting Pilot Project continues to make good progress. Four radars covering much of the western half of the country are now linked into a single experimental network, the data from all four being incorporated into a single composite rainfall display which can be updated every 15 minutes and transmitted in digital form to the user. The radar patterns, with different rainfall intensities showing as different colours on a television screen, can be interleaved with half-hourly cloud pictures from the Meteosat geostationary satellite and sequences of such pictures can be replayed to reveal the movement and development of weather systems over much shorter time- and space-scales than can be achieved with numerical models or by any other observing system. The objective of this project is to develop methods for more accurate forecasts of local weather for up to about 12 hours ahead.

Improvements have been made in the operational forecasting of the state of the sea surface. Using forecast surface winds from the atmospheric models, the sea-state model predicts the growth of the wind-generated waves and also the

propagation of the swell, both of which are important for the routeing of ships, the towing of oil rigs and in the warnings of coastal flooding. The output of the model is also being used by the Energy Wave Project to investigate the potential for obtaining energy from sea waves around the coasts of Britain. The Office continues to operate a storm-surge prediction model developed by the Institute of Oceanographic Sciences for the North Sea and consideration is being given to the use of a finer-mesh model for the west coast and the Thames Estuary.

Continued delay in the commissioning of the enhancement of the automated telecommunications system is of serious concern and strong pressure is being exerted on the firm responsible for getting this operational within the next few months. Meanwhile the staff has shown great ingenuity in stretching the existing system to cope with the major increase in traffic during the Global Weather Experiment.

An order was placed for a new computer, the CDC 203E, which will be at least ten times faster than our present IBM 360/195 machine. Delivery is expected early in 1981; meanwhile programming of new weather and climate models is being carried out by our scientists on a prototype model of the computer in the United States.

Unfortunately the European geostationary satellite, Meteosat, ceased to operate in December after functioning perfectly for two years. It will not be possible to replace this satellite before September 1980 when a launch on the Ariane rocket is planned.

Meteosat, like the four other geostationary satellites, performed excellently during the year of the Global Weather Experiment and produced not only high-quality images but also a large number of wind vectors from cloud displacements which filled important gaps in observations from the tropical and oceanic areas.

Our second stratospheric temperature sounding instrument was launched on the NOAA-6 satellite in June and has functioned perfectly. The data are being processed at Bracknell to produce daily maps of geopotential from pressure surfaces between 100 and 1 millibars. Work has continued on six more units which will be launched during the next five years.

The Meteorological Research Flight has concentrated this year on gathering and analysing data from the atmospheric boundary layer over the sea. The results show, for the first time, substantial differences in the structure of the turbulence sampled along-wind and across-wind and also the importance of density variations due to humidity in producing and maintaining the turbulent fluxes. In a collaborative project with the Central Electricity Research Laboratories, designed to study the fate of sulphur dioxide emitted into the atmosphere by power stations, the Hercules aircraft is being fitted with apparatus for collecting cloud-water, rain-water, particulates and air samples for later chemical analysis whilst the concentrations of sulphur dioxide, oxides of nitrogen, ozone and the acidity of cloud-water and rain-water are measured during flight. Full-scale experiments are planned for 1980.

The aircraft has also been fitted with a gas chromatograph to sample a number of trace chemicals, particularly chlorofluorocarbons (CFCs) whose photo-dissociation is likely to lead to partial destruction of stratospheric ozone. Five flights were made from Dakar within and outside Saharan dust plumes to test the hypothesis that CFCs may be removed from the atmosphere by adsorption on dust particles. Computer models have been developed to investigate the effects of CFCs, carbon dioxide and nitrous oxide on the stratospheric ozone layer. They indicate that the expected increase in carbon dioxide resulting from the burning of fossil fuels will lower the temperature of the stratosphere

and thereby increase the ozone and partly offset any depletion of ozone by the emission of CFCs from aerosol sprays and refrigerators.

The important studies on the formation and dissipation of fog and stratocumulus cloud, carried out over the last five years by the Cloud Physics Branch, are the subject of the special topic on page 00.

At the Meteorological Office College, a record number of 714 students completed courses during the year and the postgraduate course with 23 students was a large one. Seventy-three overseas students came from 26 countries. The 1979 recruitment exercise was very successful with 50 graduates, including many with first-class honours and PhDs, joining the Office.

B. J. MASON

March 1980
Meteorological Office
Bracknell, Berks.

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FUNCTIONS OF
THE METEOROLOGICAL OFFICE

The Meteorological Office is the State Meteorological Service. It forms part of the Air Force Department of the Ministry of Defence. The Director-General is responsible to the Secretary of State for Defence through the Parliamentary Under-Secretary of State for Defence for the Royal Air Force.

The general functions of the Meteorological Office are:

(a) The provision of meteorological services for the Army, Royal Air Force, civil aviation, the merchant navy and fishing fleets; provision of basic meteorological information for use by the Royal Navy; and liaison with the Director of Naval Oceanography and Meteorology.

(b) The provision of meteorological services to other government departments, public corporations, local authorities, the Press, television, radio, industry and the general public.

(c) The organization of meteorological observations, including observations of radiation, atmospheric electricity and ozone, in the United Kingdom and at certain stations overseas.

(d) The collection, distribution and publication of meteorological information from all parts of the world.

(e) The maintenance of the observatories at Kew and Lerwick.

(f) The provision of professional training in meteorology.

(g) Research in meteorology and geophysics.

The Meteorological Office also takes a leading part in international co-operation in meteorology. The Director-General is the Permanent Representative of the United Kingdom with the World Meteorological Organization, and acts in concert with the other Directors of the Meteorological Services in western Europe in the co-ordination of their programs.

COMMITTEES

METEOROLOGICAL COMMITTEE

Terms of reference:

(a) To keep under review the progress and efficiency of the Meteorological Service and the broad lines of its current and future policy.

(b) To keep under review the general scale of effort and expenditure devoted to the meteorological services.

(c) To ensure the maintenance of adequate contacts between the Meteorological Service and those who use its services.

Membership at 31 December 1979:

Chairman:	The Earl of Halsbury, F.R.S.
Members:	Dr J. Birks, C.B.E.
	Professor A. H. Bunting, C.M.G.
	Sir Frederic Harmer, C.M.G.
	Professor J. T. Houghton, F.R.S. (Chairman, Meteorological Research Committee) (*ex officio*)
	Sir Norman Rowntree
Secretary:	Mr A. C. Hughes (Secretary, Meteorological Office)

The Committee met twice in 1979.

ADVISORY COMMITTEE ON METEOROLOGY FOR SCOTLAND

Terms of reference:

(a) To review the development of meteorological science and its application to Scotland.

(b) To submit to the Meteorological Committee any proposal in connection therewith.

Membership at 31 December 1979:

Chairman:	Sir John Mason, C.B., F.R.S. (Director-General, Meteorological Office)
Members:	Mr S. C. Agnew (Scottish Development Department)
	Mr R. J. H. Brush (University of Dundee)
	Mr R. W. Buchanan (Association of Consulting Engineers)
	Dr J. M. Caborn (University of Edinburgh)
	Sir Samuel C. Curran, F.R.S.
	Mr H. D. Dooley (Department of Agriculture and Fisheries for Scotland)
	Mr J. Ferguson (Department of Agriculture and Fisheries for Scotland)
	Dr S. J. Harrison (University of Stirling)
	Professor G. M. Howe (University of Strathclyde)
	Mr R. Lines (Forestry Commission)

Dr D. H. McIntosh, O.B.E., F.R.S.E. (Department of Meteorology, University of Edinburgh)
Mr J. Miller (Federation of Civil Engineering Contractors)
Dr I. S. Robertson (University of Aberdeen)
Professor S. D. Smith, F.I.P., F.R.S. (Heriot-Watt University)
Professor D. W. N. Stibbs, F.R.S.E. (University of St Andrews)
Mr R. J. C. Stobie(Convention of Scottish Local Authorities)
Professor P. A. Sweet (University of Glasgow)

Secretary: Mr J. S. Hopkins (Meteorological Office, Edinburgh)

The Committee met once in 1979. In December the Secretary of State for Defence, in his review of non Government Departmental organizations, decided that the Committee should be abolished and its functions assumed by the Meteorological Committee.

METEOROLOGICAL RESEARCH COMMITTEE

Terms of reference:

The Meteorological Research Committee will advise the Parliamentary Under-Secretary of State for Defence for the Royal Air Force on the general lines along which meteorological and geophysical research should be developed within the Meteorological Office and encouraged externally. It shall review progress and report annually.

It is empowered to appoint subcommittees, one of which shall be responsible for advising on the use of money allocated annually from Defence Votes for research projects conducted outside the Meteorological Office. The Committee will be responsible for co-ordinating the work of its subcommittees.

Membership at 31 December 1979:

Chairman: Professor J. T. Houghton, F.R.S.

Members: Mr F. H. Bushby (Director of Services, Meteorological Office)
Professor H. Charnock, F.R.S.
Professor D. R. Davies
Captain F. J. Edwards, R.N. (Director of Naval Oceanography and Meteorology)
Mr A. Gilchrist (Deputy Director, Dynamical Research, Meteorological Office)
Mr P. Goldsmith (Deputy Director, Physical Research Meteorological Office)
Professor J. Latham
Sir John Mason, C.B., F.R.S. (Director-General, Meteorological Office)

Professor R. P. Pearce, F.R.S.E.
Mr O. B. St John (Civil Aviation Authority)
Mr J. S. Sawyer, F.R.S.
Mr K. W. Smith (Procurement Executive, Ministry of Defence)
Dr K. H. Stewart (Director of Research, Meteorological Office)
Wing Commander A. R. Tolcher (Air Force Department)
Dr P. F. G. Twinn (Natural Environment Research Council)

Secretary: Mr. R A. Ebdon (Meteorological Office)

The Committee met three times in 1979 and its subcommittees seven times. In December the Secretary of State for Defence, in his review of non Government Departmental organizations, decided that the Committee should be abolished and its functions assumed by the Meteorological Committee.

PRINCIPAL OFFICERS OF THE METEOROLOGICAL OFFICE

DIRECTOR-GENERAL

Sir John Mason, C.B., D.Sc., F.R.S.

DEPUTY TO THE DIRECTOR-GENERAL

K. H. Stewart, Ph.D.

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CENTRAL FORECASTING Assistant Director	D. E. Jones, M.Sc., D.I.C., A.R.C.S
DEFENCE SERVICES Assistant Director	I. J. W. Pothecary, B.Sc., M.Inst.P.
Chief Meteorological Officer, H.Q. Strike Command	A. G. Forsdyke, B.Sc.
PUBLIC SERVICES Assistant Director	R. J. Ogden, B.Sc.
Chief Meteorological Officer, London/Heathrow Airport	A. Ward

COMMUNICATIONS AND COMPUTING

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TELECOMMUNICATIONS Assistant Director	D. McNaughton
DATA PROCESSING Assistant Director	P. Graystone, B.A.
SYSTEMS DEVELOPMENT Assistant Director	R. L. Wiley, Ph.D.

OBSERVATIONAL SERVICES

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OBSERVATIONAL REQUIREMENTS AND PRACTICES	
Assistant Director	D. R. Grant, B.Sc.
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CLIMATOLOGICAL SERVICES	
Assistant Director	C. R. Flood, M.A.
AGRICULTURE AND HYDROMETEOROLOGY	
Assistant Director	C. V. Smith, M.A., B.Sc.
OPERATIONAL INSTRUMENTATION	
Assistant Director	D. N. Axford, Ph.D., C.Eng., M.I.E.E.

DIRECTORATE OF RESEARCH

DIRECTOR	K. H. Stewart, Ph.D.

PHYSICAL RESEARCH

DEPUTY DIRECTOR	P. Goldsmith, M.A.
GEOPHYSICAL FLUID DYNAMICS LABORATORY	
Head of Branch	R. Hide, Sc.D., F.R.S.
BOUNDARY LAYER RESEARCH	
Assistant Director	C. J. Readings, Ph.D., D.I.C., A.R.C.S.
Special Post	F. B. Smith, Ph.D.
METEOROLOGICAL RESEARCH FLIGHT	
Chief Meteorological Officer	D. G. James, Ph.D.
METEOROLOGICAL OFFICE RADAR RESEARCH LABORATORY	
Chief Meteorological Officer	K. A. Browning, Ph.D., D.I.C., F.R.S.
CLOUD PHYSICS	
Assistant Director	P. Ryder, Ph.D.
HIGH ATMOSPHERE	
Assistant Director	D. E. Miller, B.A.

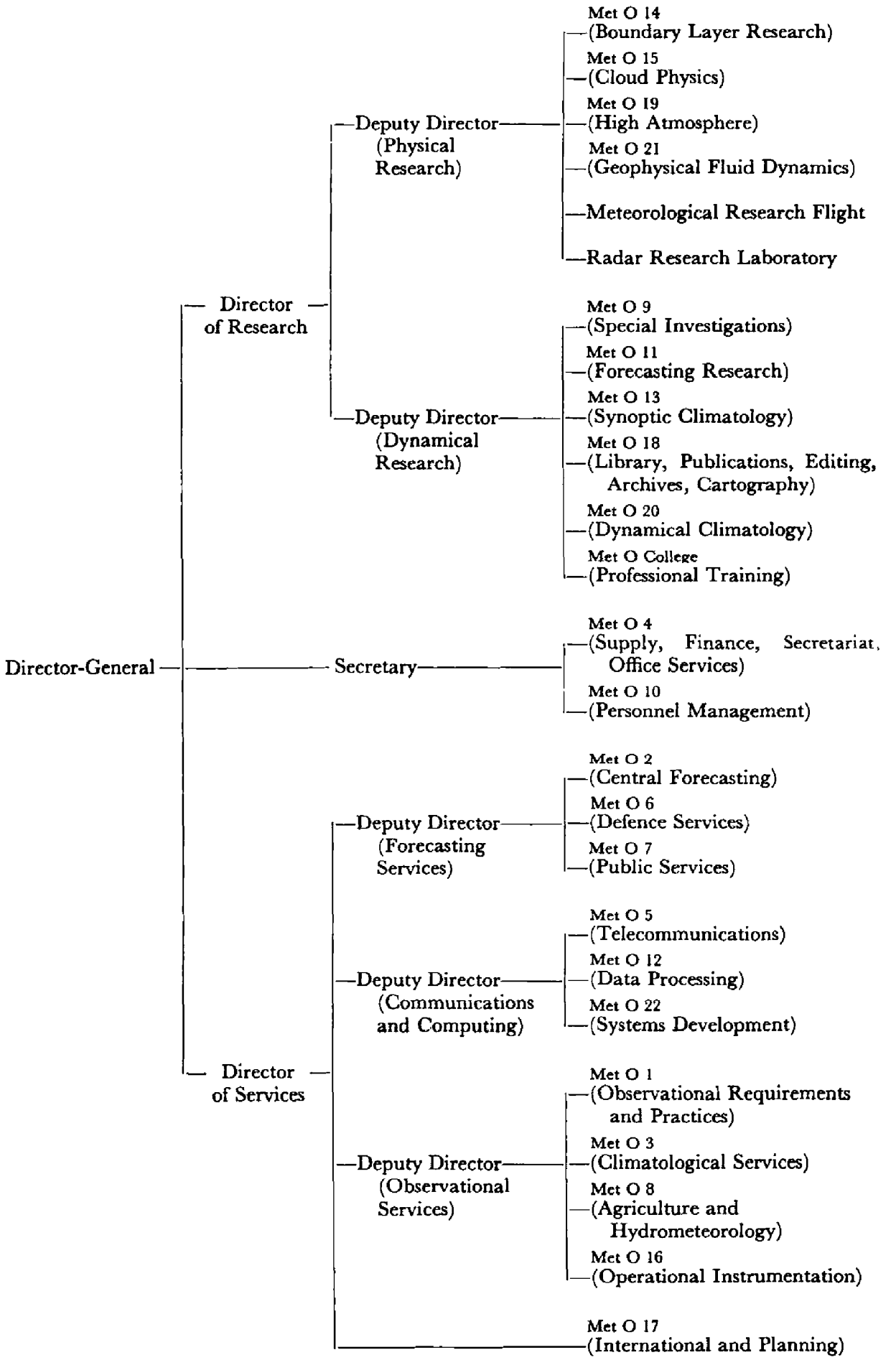
DEPUTY DIRECTOR	A. Gilchrist, M.A.
SPECIAL INVESTIGATIONS	
Assistant Director	W. T. Roach, Ph.D., D.I.C.
FORECASTING RESEARCH	
Assistant Director	P. W. White, Ph.D.
Special Post	R. Dixon, B.Sc.
SYNOPTIC CLIMATOLOGY	
Assistant Director	D. M. Houghton, M.Sc., D.I.C.
PROFESSIONAL TRAINING	
Assistant Director and Principal, Meteorological Office College	S. G. Cornford, M.Sc.
DYNAMICAL CLIMATOLOGY	
Assistant Director	A. J. Gadd, Ph.D.
Climate Modelling	P. R. Rowntree, Ph.D.

ADMINISTRATION, FINANCE AND SUPPLY

SECRETARY, METEOROLOGICAL OFFICE	A. C. Hughes, M.Sc., M.Phil. (To be succeeded by F. R. Howell, M.B.E., F.C.I.S. in January 1980)
PERSONNEL MANAGEMENT	
Assistant Director	F. Singleton, B.Sc., D.I.C.

METEOROLOGICAL OFFICE ORGANIZATION

(at 31 December 1979)


Director-General
Director of Research
Deputy Director (Physical Research)
Met O 14 (Boundary Layer Research)
Met O 15 (Cloud Physics)
Met O 19 (High Atmosphere)
Met O 21 (Geophysical Fluid Dynamics)
Meteorological Research Flight
Radar Research Laboratory
Deputy Director (Dynamical Research)
Met O 9 (Special Investigations)
Met O 11 (Forecasting Research)
Met O 13 (Synoptic Climatology)
Met O 18 (Library, Publications, Editing, Archives, Cartography)
Met O 20 (Dynamical Climatology)
Met O College (Professional Training)
Secretary
Met O 4 (Supply, Finance, Secretariat, Office Services)
Met O 10 (Personnel Management)
Director of Services
Deputy Director (Forecasting Services)
Met O 2 (Central Forecasting)
Met O 6 (Defence Services)
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Deputy Director (Communications and Computing)
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Met O 22 (Systems Development)
Deputy Director (Observational Services)
Met O 1 (Observational Requirements and Practices)
Met O 3 (Climatological Services)
Met O 8 (Agriculture and Hydrometeorology)
Met O 16 (Operational Instrumentation)
Met O 17 (International and Planning)

THE DIRECTORATE OF SERVICES

SPECIAL TOPIC—AGRICULTURAL METEOROLOGY

Introduction

Serious development of agricultural meteorology as an applied science commenced after the Second World War, although pioneering efforts by a few individuals date from earlier years. The spur came mainly from two sources. One was the widely publicized fear that world population would outstrip food production resources in the then not too distant future; the other was the realization by a section of the meteorological community that considerable economic benefit might accrue from the application of meteorological knowledge and techniques which, until then, had been largely devoted to the operation of aircraft.

Within the Office in the late 1940s work commenced along two paths. A small section was formed under the direction of Mr L. P. Smith, which sought to apply available data to the more immediate problems facing the farmer, and a cell was located at Cambridge in co-operation with the University School of Agriculture to undertake research which was thought to be important to longer-term agricultural problems. Initially it was necessary for members of both these units to familiarize themselves with agricultural practices so that their efforts would be directed to the solution, in the short and long terms respectively, of real issues. In the event, in the 20 or so years of its existence (up to *circa* 1970) the unit at Cambridge made significant contributions to our understanding of the physical processes which occur in the lower layers of the atmosphere and in the surface layers of the soil in which plants and animals live.

Initially the other unit concentrated on the establishment of largely empirical relationships which permitted advice to be given to help in day-to-day farming practice. We should note, in passing, that as far as the practical end result is concerned an empirical solution is as good as one based on physical or biological insight although, instinctively, the scientist seeks such insight and feels much more comfortable when it is achieved. The underlying philosophy of the small group of people which began this work 30 years ago has stood the test of time. The majority now so engaged are located at the regional offices of the Agricultural Development and Advisory Service (ADAS) of the Ministry of Agriculture, Fisheries and Food.

They take their problems from this Service, or from the individual farmer, and are effectively integrated with the advisory service. They assimilate much of the understanding of the general agriculturist and operate as environmental specialists, drawing on their basic training in physics and mathematics and their familiarity as meteorologists with atmospheric motions and processes. The likelihood or impact of climate variability lies as much within their ambit as does the visualization and modification of the air movement within an animal house. Individuals are expected to contribute in depth in their investigational work to certain specialist fields such as crop growth studies, plant or animal pest and disease problems, animal production problems, etc. The number of meteorologists allocated to work with agriculturists has increased slowly and we now find groups of from 2 to 4 people in the ADAS Regions at Bristol, Reading,

Cambridge, Harrogate, and at Edinburgh where there is liaison with the Department of Agriculture and Fisheries for Scotland (DAFS).

Agricultural meteorologists in the field are complemented and supported by a small group at Bracknell. This proves essential in order to provide outstation staff with access to the facilities available through the Meteorological Office COSMOS computing system. Significant procedural changes in the work have taken place over the past 5 or 6 years, as people have sought to exploit the machinable archives and available computing power. Just as important is the lifting of horizons and the reassessment of the problems that might be tackled. Projects which could not have been contemplated at the time of the last review of work in 1966 have been set in hand.

Operational services

To further agricultural and hydrometeorological applications, a new archived, machinable data set has been produced from a variety of sources such as the daily climatological station reports of co-operating observers and authorities and the archives of hourly and 3-hourly data from Meteorological Office synoptic stations. This data set brings together in one place information needed to arrive at derived variables of agricultural significance such as potential transpiration. The data set has been copied to the Agricultural Research Council (ARC) Institute at Rothamsted to which many ARC units have computer links and to the Ministry of Agriculture, Fisheries and Food (MAFF) computer at Guildford, with which all ADAS Regions can now interact. Computer programs for data sorting, testing and presentation are available at Bracknell. In addition, the computer has been used to develop simulation studies of the growth and development of field crops, of plant diseases, of soil conditions relevant to field work, of the microclimate within a crop canopy and of the conditions within a stored food bulk.

Of equal significance, weather criteria for plant disease whose occurrence was previously monitored manually and notified by post, have now been rewritten so that conventional weather data received from the synoptic observing network may be employed. Such data are now automatically generated in a form suitable for direct onward transmission by Telex to the Plant Disease Intelligence Unit of ADAS, to the plant pathologists in the ADAS Regions and to the Scottish Colleges who carry out similar work in that country. The Meteorological Office Rainfall and Evaporation Calculating System (MORECS) also extracts information from the weather reports arriving at frequent intervals from the same network to provide a weekly bulletin of evaporation and of the soil moisture conditions under a variety of crops. Both the agricultural and water industries subscribe to this publication.

The MAFF *Technical Bulletin* on 'Calculation of Irrigation Need' is in the process of being rewritten and will again contain a substantial Meteorological Office contribution. It will indicate the availability of an individual service to growers, to be operated through the Meteorological Office computer and data banks, in which the irrigation-water requirements for specific sites, crop rotations and soil types may be determined more precisely than at present. In addition to evapotranspiration estimates, understanding of the extraction of soil moisture by field crops is implied. Soil moisture profile measurements by others, using 'neutron probe' equipment, have been analysed with this problem in

mind. Both the current MORECS statement and that on plant disease and pests are available on Prestel, the Post Office data-presentation service, as are current weather observations, forecasts and summaries of past weather (climate) statistics.

The agricultural climate of Britain

It is fashionable to claim that climate is a resource. To the extent that a particular climate may facilitate one type of crop or animal production rather than another, this may be true. The UK producer of fruit may envy the European or South African advantages of regularity and ease of production. A distinction should be made between those climate limitations which cannot be modified by any intervention of the farmer (such as the variation with latitude of solar radiation available for photosynthesis) and those limitations which arise out of the combination proposed for the plant, soil, land-form and climate which are subject to intervention and manipulation by management. A similar distinction can be made between climate or atmospheric hazards which cannot be controlled (such as summer storms) and the charges on production systems which can be lessened or counterbalanced to a degree through technologies which reduce weather-sensitivity, e.g. combining machines that can pick up lodged crops and cover the ground quickly. In the one case we have to state the climate facts and risks as we see them; in the other we have to understand plant–soil–atmosphere interactions and requirements in order to help the farmer prepare for inclement weather or to suggest procedures which will shelter production from the worst effects of the environment. Thus, there is a need to state simply the typical weather of the country and its regions, to indicate the typical departures from average and to suggest the degree of risk associated with particular weather hazards or increasing scales of severity. Each year, land is lost to agricultural production, being taken for other purposes. Given options of equal merit, one would like to feel that planners took the land of least agricultural value. It follows that there is a need to classify land according to its agricultural potential. This assessment necessarily includes some meteorological comment.

The publication of 'The Agricultural Climate of England and Wales', one of a series of *Technical Bulletins* issued by MAFF, was the culmination of many years of work by members of the Meteorological Office. The *Bulletin* contains a wealth of agriculturally significant 'weather' information, including derived data as well as the more obvious meteorological variables such as temperature, sunshine and rainfall, for each of 56 regions. Information on the length of the growing season, evapotranspiration values and soil water-balance data, drought frequencies, frost 'degree days', 'degree days' above the threshold for growing maize, etc. are included. The monthly mean values of various parameters are accompanied by information on likely features of a 10-year distribution (i.e. extreme and quartile values) and also by information on the expected variation with height above mean sea level. A similar description of the agricultural climate of Scotland is under preparation in the Edinburgh Office.

A consensus on the broad pattern of agricultural land use in Britain was established long ago with grassland utilized by animals in the wetter north and west and more arable production in the drier east. Whilst soil characteristics, together with aspect, altitude and slope are dominant factors in any classification of the agricultural potential of land, the memoirs and maps

published by the Soil Survey of England and Wales on this matter have had climate hazards included as integral parts of the reports. The way in which conventional climate variables might be used in this regard has been a subject of some thought. The basic elements to be employed, temperature and soil moisture, have never been in doubt. These have now been expanded into variables which take note of recent advances in understanding of plant physiology (leaf growth as a function of temperature) and of the need to utilize and manage crop production. For example, access for animals and machinery is a function of soil wetness. In this way it proves possible to quantify some old truths.

Authorship of the MAFF *Technical Bulletin* 'The Agricultural Significance of Winter Rainfall in England and Wales' was a joint effort by the Meteorological Office and MAFF. This *Bulletin* presents the essential statistics on an important variable, namely the date of return to 'field capacity'. Broadly, evapotranspiration by vegetation exceeds rainfall in the spring and summer months and the crop draws on reserves of moisture in the soil. The time at which these reserves are restored (the return to 'field capacity') indicates that further rainfall has to be removed by surface run-off, by drainage systems, or by deep percolation to ground water and aquifers. Heavy loads imposed by machine or animals after this time present the risk of severe structural damage to the soils or to soil cover ('compaction' by machines or by animals). The *Bulletin* goes on to show how field drains should be sized to cope with the expected excess winter rains in each locality.

The agricultural microclimate

Specification of the crop environment is important in a variety of studies including, for example, leaf photosynthesis and respiration, the spread of fungal diseases, the growth of newly sown crops and grass in the early spring and the wilting of silage and the field-drying of hay. The standard observations of air temperature at a height of 1.5 metres and of soil temperatures at 30 cm depth, are often inadequate to describe the crop environment in the required detail. Studies have begun recently to calculate soil temperature and soil heat flux in the top few centimetres from standard synoptic observations. A multi-layer model of crop canopies has been constructed to estimate evaporation of rain or dew from a canopy and the duration of leaf wetness. This model is being applied in a simulation study of the field-drying of hay; a future extension will be to the field-drying (and so moisture content) of standing grain.

Any study of the means of dispersal of plants, pathogens and insects to new sites reveals a number of ingenious procedures which enable seeds, spores, etc. to break through the confining layer of air in immediate contact with vegetation, and into the boundary layer. Once airborne, the possibility exists of transport to great heights and on a global scale, whilst residence times in the atmosphere can be measured in days rather than seconds. Aerobiology is a study in its own right, but draws on the quantitative understanding of the diffusion and behaviour of parcels of air and the passive agents they carry.

It is possible to point to several innovative applications of these ideas in agriculture. Through trajectory studies, source regions of races of Yellow Rust new to the United Kingdom were shown to lie in North Africa and Spain. The apparent random outbreaks of 'Newcastle Disease', which ravaged intensively

housed poultry flocks across the United Kingdom in the late 1960s were accounted for through diffusion studies, which were able to relate location and timing of outbreaks to wind-borne passage of virus from initial foci of disease. This work was extended to take in later 'foot-and-mouth' epidemics of cattle and pigs, and currently forms the basis for indicating where preventive measures should be concentrated in any future outbreak.

Airborne contaminants and pollution can be of considerable economic significance but particularly so when production takes place within buildings and ventilation and dilution are restricted. The downwash of plumes from nearby boiler chimneys is now accepted as a source of sulphur dioxide and a reason for the abortion of tomato fruits, though the problem was puzzling until the meteorologist was brought in. The siting of animal houses and the role of local topography in determining wind flow over and through the buildings has been demonstrated to be a significant factor in their performance. Inside such buildings, the patterns of air movement have to achieve an effective dilution of the contaminants introduced by the occupants. Expertise on these aspects of the evaluation of intensive animal housing, and on instrumentation and data interpretation, has been provided for a succession of ADAS livestock specialists.

Grassland matters

The growth and utilization of grass is of major importance in the agricultural economy of the country. Despite its familiarity to the layman, good grassland farming is not simple. The crop is a perennial one, harvested several times in the year by means of grazing and cutting. These repeated interventions place a need for subsequent recuperative spells of good growing weather, and the growth pattern, quality and yield are determined by the inseparable mix of the system of management and the weather sequences of the season.

Early work in the Meteorological Office on grassland problems was mainly concerned with the effect of soil moisture on the summer growth of grass, with the effect of temperature on spring and autumn growth and on sequences of dry days for haymaking. In the last few years these problems have been studied in greater detail. Understanding was greatly aided by the secondment of a meteorologist to the Grassland Research Institute of the Agricultural Research Council between 1968 and 1972. A further such appointment may well be made in 1980, primarily for work on the harvesting (field-drying) of the crop. The importance of the balance between current rainfall and evaporation in determining grass growth explains the relative success of the simple concept of 'effective transpiration' in estimating hay yields and summer grass growth, though this approach does not accommodate the spring maximum in growth rates in the absence of moisture stress. A simple model of grass growth in relation to day-to-day changes in soil moisture has been developed. One application has been to identify which periods of the summer in a variety of climate zones are likely to show a shortage of grass for grazing in a large number of years. These expectations can be written into farm management plans, whilst early warning can be given of the risk of shortage in a particular year. The timing and the amount of the spring application of nitrogen in a particular year need further study, since a balance must be drawn between the desire to encourage early grass growth if weather conditions are right and the risk of leaching if application is followed by a prolonged cold wet period.

Arable production

The main questions are still the basic ones of relations between weather and crop yield and the role of weather in determining agricultural land use and the areas allocated to different crops. Fundamental work on cereal growth at institutes of the Agricultural Research Council has allowed simulation modelling of cereal crops by Meteorological Office staff. Calculation is made of the dry matter produced by a crop from weather data (potential photosynthesis being modified by any occurrence of plant moisture stress) and from plant information (leaf area). In much of farming it is the quality as much as the quantity of the product which determines the economic return. Some work on this subject concerned the nitrogen content of cereals, of interest to brewers and bakers.

Among problems that needed a fairly rapid solution for advisory work we may note that of the frequency of weather conditions suitable for the harvest of peas and beans, the role of temperature conditions during the ripening of sugar beet seed, the most favourable areas for 'new' introductions such as maize, oil seed rape, bush tomatoes, etc. For maize, maps and statistics were developed to show the most suitable areas, whilst other work indicated probable yields.

Protected cropping

Obviously, controlled environment growing, or at least protected cropping, cannot be achieved for many field crops. Irrigation represents a major intervention into the 'weather' of the growing season and assumes increasing importance for high value, intensively produced crops, grown to a uniform standard. In the late 1960s, a member of staff was responsible for preparing 'The Atlas of Long Term Irrigation Need' which became the standard work of reference for those wishing to make the best estimates of total and peak water demand during the growing season. Further developments in this area already mentioned are bringing about greater flexibility and accuracy to this long-term planning aid, whilst advice on the short-term, day-to-day running of irrigation installations is given by the MORECS bulletin.

Numerous studies have been made (together with ADAS) on commercial holdings as well as on Experimental Stations, into the microclimate of plastic houses, bubble houses and under low plastic tunnels and mulches (a system for modifying soil microclimate by reducing moisture loss and increasing soil temperature). In addition, techniques that set out to modify the free wind and shelter 'soft' crops have been explored. A detailed analysis of the occasions of 'wind blow' of soils in East Anglia was undertaken by a forecasting office in that region and a warning service is operated using criteria developed in the course of the analysis.

The horticultural industry has been active in developing techniques of frost protection and prevention. Studies have enabled the necessary climatology to be developed for the main horticultural areas. The preferred arrangement, however, is to avoid frost-prone sites and a standard service is available to assess frost risk on potential horticultural sites before any substantial investment is undertaken.

Members of staff have investigated heat loss from glasshouses in relation to wind speed and outside air temperature. Calculations have shown that between 3 and 6 per cent of total annual fuel consumption can be saved by an effective shelter belt sited to give protection from winds up to 45 degrees on either side of prevailing wind direction. Shelter from all directions might give savings up to 12

per cent. Extreme conditions can be estimated from past occurrences and hence economic costings can be made for most areas. The effectiveness of internal screens to reduce heat loss has been the subject of study since the fuel crisis of a few years ago.

More fundamental work involved early computer-based studies of the solar radiation falling on crops within glasshouses of differing orientation. The inflexible requirement for east–west or north–south orientation that many growers adopted in order to optimize 'light' input into the house was shown not to be strictly necessary (within limits) and this relaxation enables better planning of site facilities in many instances.

The growing of vines for wine on a commercial scale has continued to attract a steady succession of aspirants; enquiries for climate information about possible sites, and in some cases unlikely sites, continue to be received.

Husbandry operations

All but a few farming activities depend to some extent upon the state of the soil and its response to operations which change its structure, either deliberately as in ploughing, seed-bed cultivation, subsoiling, etc., or inadvertently as when the load-bearing properties of the soil are insufficient to support the weight of tractors and other vehicles. Information on the weather characteristics of days when machinery can travel and/or when other operations can be carried out without serious side effects ('workdays') enables planning and policy advice to be soundly based. Over the years it has been possible to progress from rough-and-ready rules based on recollection to soundly based studies which enable the weather criteria to be set against a consensus of farmer opinion on the suitability of days for field-work. Given such associations it is possible to look at the weather archives and to read them as archives of 'workdays' for planning purposes.

The success of farming operations depends on a number of conditions occurring simultaneously. Given, for example, that the state of the ground allows equipment to travel over it, then for crop spraying to be both effective and safe it is usually necessary for the wind speed to be below some critical value. Depending on the composition and target of the sprayed material, other conditions involving rainfall and temperature are relevant, and if aerial spraying is involved, the weather has to be conducive to the operation of low-flying light aircraft. By analysing the frequency with which sequences of hourly weather observations allow one to infer that a number of diverse crop, soil and atmospheric criteria are simultaneously satisfied, one may assess some of the consequences of changes or advances in technology.

Crop storage

Long before the advent of 'contract' growing, people had become accustomed to the year-round availability of staple farm products. Where seasonal gaps in supply were met by higher priced imports, UK growers themselves naturally looked to see how they might meet the demand. Extended storage of crops, commonly on the farm, is not new but is one obvious answer.

When field crops are taken into storage, they undergo natural decay. Even if mites, moulds, bacteria or insects were not present, crops might still have a limited safe storage life set by natural metabolic process rates. The extended storage of food bulks mostly demands low temperature. In some (but not all instances) an equally practical strategy might be to establish low humidities

within the bulk, which would also inhibit the reproductive capacity of most aerobic organisms. Further strategies are to use gas-tight stores or ones into which inert atmospheres such as nitrogen are deliberately introduced and from which respiration products are 'scrubbed'.

Work on crop storage has involved theoretical and 'on farm' studies. Though gas-tight stores might at first sight appear to exclude any interests of the meteorologist, the measurement of 'air tightness' or rather the measurement of ventilation rate by the rate of dilution of the radioactive tracer gas Krypton 85 has proved useful. Normally, however, control of the environment within bulk-stored farm products is achieved by ventilation of the bulk with the outside air. The questions now directed at the meteorologist are a little more obvious. They involve the assessment of how often outside ambient temperature (or a combination of outside temperature and humidity) is likely to be suitable for lowering the temperature of bulks without serious side-effects. Assessment of the rate of the heat and moisture exchange is needed so the volume flows and consequently the size of the engineering system can be deduced as well as the distribution system characteristics which will enable the ventilating air to carry out its function. The work is exemplified by that on onion storage which held out the prospects of a significant saving in imports. The heat balance and the temperature changes of a ventilated onion bulk over short (hourly) intervals were examined theoretically. The ventilation was assumed to be automatically controlled by thermostats. There were at that time no commercial stores equipped to operate in the manner envisaged. However, there were a few with manually controlled fans. When temperatures in these stores were in mutual agreement it was possible to make validation checks on the theoretical calculations. Following this feasibility study, automatic storage systems were built. Theoretical calculations are still made for each season as an operational tool and as a guide to the temperatures which should be achieved. Significant departures from expected temperatures are indicative of equipment failure.

Whilst onions may be a relatively unimportant crop, cereals certainly are not. With the prospect of substantial quantities of cereals being taken into 'Intervention' following membership of the European Economic Community (EEC), authorities were forced to consider how such grain might be stored. The proposal simply to place it under cover in large disused aircraft hangars was shown by the meteorologist to be inadequate. The uptake of moisture that would follow from ambient air of high humidity led to the ready prediction of a short storage life. In the course of this work it also became clear that EEC regulations on the moisture content of grain that might be bought into 'Intervention' were geared to the drier field conditions of the European mainland, and that it was reasonable to renegotiate different crop moisture levels for the rather different climate regime of the British Isles.

Animal production

Work began in the agricultural section many years ago, at a time when intensive housing of animals and poultry was becoming commonplace but when understanding of the environmental requirements of animals housed in this fashion, and of the operation of environmental control systems in intensive units, was limited. It was not uncommon for ideas and actual designs found to be effective in other climate zones to be simply translated to the United Kingdom in full

expectation that they would work equally well here. Unfortunately, this was seldom the case. At a different level, alternative animal feeds were still discussed in terms of 'starch equivalent' even though the underlying concept is really one of energy equivalence. Understanding and practice have changed dramatically since those early days and it is felt that the Meteorological Office, working with and through ADAS, contributed in some substantial way to the change.

Early work concentrated on the processes and characteristics of natural and forced-fan ventilation systems. In particular, a heat and moisture budgeting approach to arrive at the properties of the air inside an intensive unit (metabolic heat additions, ventilation heat losses, conductive heat exchanges through the fabric of the building acting in either sense) drew attention to the significant variables in the design and sizing of forced air movement systems. At this time there was much field-work in commissioning systems, in providing advice on instrumentation and expertise on monitoring procedures, and not least, in 'trouble-shooting' for the 'do-it-yourself' systems brought into being on many farms. Because of the reliance on natural ventilation systems in many instances an educative role had to be adopted on the importance of siting to the ventilation and performance of standardized animal housing units. Visualization of the air circulations within and around houses became an important advisory tool. Smoke puffers, soap bubbles, radioactive and nitrous oxide tracer gases, sampling tubes for contaminants such as carbon dioxide, ammonia, hydrogen sulphide, low-speed anemometers, all became part and parcel of the meteorologist's and the livestock specialist's field equipment.

There is a broad comfort zone where a ready balance is achieved between metabolic production and energy loss to the environment. The forced (convective) heat demand posed by a combination of wind and low air temperature can be quantified. Through a comparison of this demand with the metabolic heat produced by young beef animals of a given size and weight, it has been proved possible to map those areas of the country where there is some imbalance and where the animals might be expected to draw on body reserves over the winter period. The analysis was extended to place a value on the loss of carcass weight and on the cost of providing housing or additional feed to counteract the weight loss, so that the economics of the options might be examined. The progress of earlier work on beef cattle is documented in a sequence of publications with titles that are almost self-explanatory, i.e. 'Effect of winter environment on the growth of young beef cattle', 'The occurrence of winter temperatures relevant to the growth of young beef cattle', 'Critical temperatures of young beef cattle', 'On the response to exposure to cold of young beef cattle', 'On the economics of cold stress on young beef cattle'.

The loss of young lambs in the south of Britain (where conditions are not generally thought to be extreme) has been 'explained' through a similar 'heat budget' approach. This particular study showed that the role of land form in determining local wind flow can be assessed by relatively simple if tedious measurements and that just as surveys for frost risk are worth undertaking, so then are surveys for 'wind chill'.

Pests and diseases

In 1966, when Agricultural Meteorology last featured as a special topic in the *Annual Report*, there were weather-based warning systems for two plant diseases, namely potato blight and apple scab. Similar warning systems have

now been introduced for four other plant diseases: barley mildew, eyespot, *Septoria* and *Rhynchosporium*. Weather warnings are sent to ADAS plant pathologists but not directly to farmers. The reason is that the development of a disease to a level at which it becomes of economic importance requires both periods of suitable weather and sufficient initial innoculum in the crop. The plant pathologist interprets the weather information in the light of his field intelligence and will advise the farmer to take action only when both conditions are satisfied.

Communications between the plant pathologist and the farmer (or indeed the veterinarian and the farmer) have improved over the years and are now poised for a major expansion, but it is agreed by all that one of the most effective communication channels is through the TV weather forecaster at the end of the Sunday farming program who, having engaged farmers' attention, presents warnings and advice on behalf of the Advisory Services.

For operational reasons, the first disease-weather warnings were based on the simplest possible criteria. More detailed disease-weather relationships may now be considered, which attempt to take account of each day's weather on all phases of the life cycle and the growth of populations of the pathogen. The construction of a comprehensive computer model is a discipline that forces one to consider and quantify every interaction. It has, in the case of *Septoria* on wheat, revealed areas where basic research is required, but in the case of potato blight has led to a model that can quite adequately predict the progress of the challenge that the organisms present. Such a model may have to be simplified for operational use, but the simplifications are made against a background of wider understanding, rather than of necessity.

In the early study of the effects of weather on insect pests and vectors, much time and energy was devoted to considerations of wind-directed insect migration. Although well-established examples of long-distance flight by small insects certainly exist, it is still often a matter of conjecture whether a particular infestation, for example of aphids, is the result of the transport of a native or continental population, or a combination of the two in undefined proportions. Nevertheless, the swarms of aphids off the east coast that attracted news headlines in the summer of 1979 were shown to be of local origin. This conclusion was based in part on observations from a biological monitoring network but essentially on meteorological considerations. The rapid (exponential) increase of insect numbers when the weather favours rather than inhibits population growth is obviously helped by life cycles which are measured in days rather than weeks or months. In most cases the rate of development of the insect populations is related to temperature, with wind and rainfall regulating their dispersal and perhaps survival. Where these relationships can be quantified, there is the prospect that progress can be made.

Studies and close collaboration between the Meteorological Office and institutes such as the MAFF Central Veterinary Laboratory have led to many logical links being established between the weather and populations of animal pests or the severity of disorders arising from environmental stress. The life cycle of the pathogen or the reaction time of the host is measured in months or seasons and this long lead time enables inferences from weather data to be acted on. Techniques for forecasting disease levels from past weather data form the basis for warnings which are issued by MAFF. These cover parasitic diseases such as fascioliasis (liver fluke), nematodiriasis and parasitic gastro-enteritis, and

metabolic disorders introduced by environmental and nutritional stress, such as pregnancy toxaemia, sway-back and hypermagnesaemia. Work on virus spread by the airborne route has already been discussed.

It is perhaps useful to paraphrase some remarks written by a veterinarian in a recent World Meteorological Organization (WMO) *Technical Note* on 'Some aspects of the meteorological forecasting of animal disease'.*

'Twenty years ago it could be said that research effort to forecast animal diseases using weather data was an esoteric interest of dubious value. Since that time a large and rapidly increasing number of valuable research and Extension Service applications have been developed....

'It is paradoxical but common experience that applied research using meteorological data to analyse animal disease, produces more basic and objective research results than basic research on its own. It seems that the applied research worker quickly comes to the limit of known knowledge and his need for specific answers to a definite question fruitfully crystallizes the research effort in that area....

'The forecasting of animal diseases provides some very tangible direct advantages to the livestock industry in the planning and direction of health programmes; in the optimal use of helminthicides and acaricides (so reducing unnecessary dosing and costs); in the reinforcement of the advice given by others on the needs of animals in areas where forage is mineral deficient; in identifying specific questions for research work; in demonstrating the need for an adequate biological data base, and in the spin-off in terms of the provision of improved veterinary care as well as epidemiological control, that follows from the use of disease monitoring systems....

International activities

The contribution to the activities of the WMO technical Commission for Agricultural Meteorology has been substantial. The Meteorological Office provided the President of the Commission for eight of its formative years, in addition to members of Working Groups and Rapporteurs since that time. The United Kingdom has dominated the work of the Commission on animal health and production problems for a decade or more and, in addition to the *Technical Notes* already mentioned, provided others on problems of intensive livestock production and on the meteorological aspects of studies with animals. Other UK experience, on grain storage, on the epidemiology of wheat rusts, on the protection of plants against adverse weather, on certain insect pests, on the application on micrometeorology to agricultural problems and on aerobiology, is reported in the WMO series of *Technical Notes.*

The Office has naturally contributed to short-duration international training seminars and workshops, and has on occasion undertaken a limited amount of training of people from the Third World at Bracknell. Other Services see what has been achieved in the United Kingdom in a matter of 30 years and look to establish a similar operation in as many weeks. Unfortunately, formal courses and the assimilation of facts are not necessarily the answer; indeed no staff member has received formal training in agricultural meteorology.

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* This *Technical Note* and others on 'Weather and animal diseases' and 'Weather and parasitic animal disease' came into being through the contribution and foresight of the former leader of the Agricultural Section and his demonstration of the effectiveness of a collaborative, multidisciplinary approach to these problems.

Economic benefits

The present annual value of the UK farm output is in excess of £7000 million. The Meteorological Office annual budget is of the order £40 million and rather less than 1 per cent of staff resources is allocated to work in agricultural meteorology.

Major constraints on the farmer are those provided by weather and climate. Agricultural meteorology sets out to define the environmental system within which the farmer has to operate and to suggest ways and means and understanding to optimize production within the environmental system that is given. There are direct costs that follow from weather events (lost production when conditions depart from the optimum). Also, there are costs that arise from increased management intervention, and of increased expenditure on labour and capital to reduce, minimize, or insure against the worst consequences of adverse weather. The potential savings and benefits that should follow from the application of agricultural meteorology at the farm level can be discussed in percentage terms of the value of farm outputs. A contribution of 1 per cent in such a weather-dependent industry, amounting to some £70 million a year, seems a realistic target.

Some clear distinction is needed between events in the atmosphere that have impacts defined in physical terms of economic consequences for agricultural systems, and information about such events, which farmers act upon to change the timing of some agricultural operation or to change some part of an agricultural system exposed to weather. It is equally important to realize that useful information can be generated by monitoring and noting the weather of the recent past; such information does not carry any of the qualifications that users might normally place on forecasts of weather.

Liver fluke costs UK farmers perhaps £30 million each year. Reduction of milk yields of up to 50 per cent are attributed to liver-fluke infestations and even low levels of infection can reduce yields by perhaps 8 per cent. In beef cattle, freedom from liver fluke reduces finishing time before marketing by 25–30 days. Infestations are equally significant for sheep. It has been estimated that if farmers followed Ministry advice, which takes note of weather-based disease assessments, then the savings of drugs in a fluke-free year would be of the order £1–2 million whilst the saving in production in bad fluke years would be in the range £10–15 million.

The annual value of UK cereal production is of the order £1300 million. There are strong reasons for believing that fungal infections of only a few per cent are important. The potential loss from cereal mildew alone has been set, as a minimum, at £45 million a year. Preventative sprays are a recognized requirement of good husbandry practice. The gain in production from routine sprays in the typical year, given a moderate level of infection (10 per cent mildew), has been estimated to be £90 million. There is a general consensus, based on field experience and experiment, that fungicide applications that take note of recent and current weather offer advantages. Modern fungicides, with well-timed application dictated by a weather-based spray warning system, will clean up a 10 per cent mildew infection completely, giving a gain in production of the order £100 million.

There are some 15 000 sugar-beet enterprises in the United Kingdom. Farm work schedules and forward planning should take into account the deadline presented to the autumn root harvest on heavy land by the return to field

capacity. An extra day worked before the deadline must, in a wet autumn, equate with at least two days' work after the deadline in achieving the same result. The information presented in the MORECS bulletin holds out the prospect of work saving in the wet season. Whilst it is true that an early harvest carries the penalty of reduced yield and perhaps the penalty of additional storage charges, these might be regarded as compensated for by the avoidance of damage to the soil, with its implied yield reduction over several subsequent cropping seasons. If one-third of enterprises are considered at risk in a wet season and for each there is a saving of 4 work days if weather-based advice is taken up, then the potential saving in many years, at say £25 a day, is £0.5 million a year (a sum intended to exclude the fixed costs of labour and other inputs).

There are some 200 000 farm holdings in England and Wales. Each is likely to operate several tractors. Let us suppose each tractor is renewed at 6-year intervals, half being new and half being second-hand. The incremental cost of buying a new tractor in the next higher power range may be £2000; for a second-hand tractor, the corresponding figure is £1000. The annual market for tractors is around 70 000 units. If as a result of advice on 'weather windows' and 'machinery workdays' the pressure to buy an over-powered machine is completely resisted, then potential saving of investment capital is £105 million a year. Taxation advantages to the farmers might reduce the figures to £25 million. If those situations where the cost of a higher-powered machine is consciously balanced against the savings from increased work rates (or rather, reduced labour costs) are left out and it is assumed that only the decisions of one farmer in a hundred are to be influenced by the implied weather-based input, the saving of investment capital amounts to £0.25 million a year. The argument can obviously be extended to other equipment.

It is clear from these above examples that the return on operational agricultural services alone contributed to or provided by the Meteorological Office could in themselves, on conservative estimates, equal the entire cost of 'meteorology' in the United Kingdom. If savings in capital costs are also included the total economic return of meteorological services to agriculture is several hundred times their direct cost.

OTHER WORK OF THE DIRECTORATE OF SERVICES

Forecasting Services

Central Forecasting Office

The Central Forecasting Office (CFO) is continuously developing but its main functions have remained unchanged for a number of years. At the national level as the chief forecasting centre of the Meteorological Office, its principal tasks are twofold. First, it provides guidance to the Meteorological Office outstations by land-line, facsimile and teleprinter in the form of charts showing actual and expected synoptic situations, with advisory texts covering the following three days, and charts of plotted observations. Second, it is responsible for the routine issue of forecasts for sea and land areas, and for warnings of weather hazards including gales, fog, snow, heavy rain, frost, icy roads, thaw and thunderstorms over and around the United Kingdom; these are disseminated by radio, television and the Press, but some forecasts are also issued direct to public utilities such as the British Gas Corporation or the Central Electricity Generating Board.

CFO is a Regional Meteorological Centre in the World Weather Watch system of the World Meteorological Organization and as such is responsible for providing forecasts and advice (mostly in chart form) to a number of European National Meteorological Centres. The area covered includes a large part of the North Atlantic, Europe and the Arctic.

Analyses and forecasts continue to be produced in CFO by a combination of numerical (computer) methods and subjective (manual) methods. The observational data are processed by computers which provide analyses and forecasts. The numerical processes are monitored by the forecasters who may modify the products in the light of their experience of the behaviour of weather systems, their knowledge of the characteristics of the numerical analysis and forecast models, or because of suspected errors in the data used. The forecasters also take into account information not available in the numerical system such as observations that have been received too late or data that have been derived from the interpretation of satellite pictures.

The two forms of the 10-level numerical forecasting model, the coarse-mesh (octagon) version covering most of the northern hemisphere and the fine-mesh (rectangle) version giving more detailed coverage including rainfall forecasts for Europe and the North Atlantic, continue to provide the basic guidance. Both versions of the model are run twice a day following the collection of observations for 00 GMT and for 12 GMT. Additional fine-mesh forecasts based on observations made at 06 GMT were introduced in 1978 and continue to be made as routine; they provide the Senior Forecaster with extra guidance in good time for it to be taken into consideration each afternoon when preparing the forecasts for the following day. Numerical guidance forecasts based on 12 GMT observations usually become available too late to be taken fully into account during the afternoon. The transmission to the Principal Forecasting Offices at London Airport and Headquarters Strike Command of analyses and prognoses of surface pressure, 1000–500 mb thickness and forecast rainfall from the fine-mesh model has continued during 1979.

Forecasts for two and three days ahead are disseminated internationally and issued to meteorological offices throughout the country. They form the basis of forecasts for agriculture and for manufacturing and building industries as well

as for the general public, and are particularly useful in forecasting for the offshore oil industry. Forecast charts for four or five days ahead are produced daily by the subjective modification of the numerical forecasts by the Medium-range Forecasters; they have been used in CFO for several years for providing extended guidance and from April they have been used to provide the basis for an extended weather outlook issued during the late evening each day on BBC Radio 4. Forecast charts for up to 7 days ahead are now being received from the European Centre for Medium Range Weather Forecasts and are available on an experimental basis to the Medium-range Forecasters who are assisting scientists in the Forecasting Research Branch to assess these new products.

Under the Area Forecasting System of the International Civil Aviation Organization, the aviation forecasters in CFO provide briefing documentation showing forecast upper winds and temperatures for aircraft flying from western Europe to North America, and for flights from Africa and the Middle East into western Europe. Special documentation is prepared twice a day for flights across the Atlantic by Concorde aircraft of Air France and British Airways and is also prepared three times a week for Concorde flights to Bahrain.

Temperature forecasts are required for supersonic flights at 100 mb (about 50 000 ft) which is the highest level of the numerical forecasting model. Trials are under way, therefore, of a model which has an additional level at 50 mb (about 65 000 ft) and results so far indicate that this has brought an improvement to the numerical guidance not only at 100 mb but also at some of the levels near the tropopause as well. The lower levels of the fine-mesh model were used very successfully for forecasting snow during the 1978/79 winter season when there was a high incidence of snowfall. The use of the model in forecasting low-level cloud has been investigated, but so far this work has not yet met with success, partly because of the rather large separation of the model levels in the vertical near the ground. A measure of success has been attained however in the use of model guidance in the forecasting of temperature change.

The performance of the numerical forecasting models is monitored by calculating statistics of model forecast errors; the forecasts are compared either with the actual observations made at the forecast validation time or with the analyses which are based on these observations. A full verification of both types is now made for both versions of the 10-level model. The statistical verification results are an important tool in assessing the value of modifications to the models, although subjective assessments also have to be made to determine whether there have been any improvements in the forecast fields from the synoptic point of view.

In its capacity as a Regional Meteorological Centre, the Office distributes numerical products to certain centres in the European Region by land-line and radio. To allow even wider dissemination of this material in future through the Global Telecommunication System, a new numerical output in a new standardized GRID-code format using a latitude–longitude grid of points has been programmed. Coded forecast output is also sent to British Airways in GRID-code, but it has been agreed that a code more generally acceptable to airlines shall be used for aviation forecast data and preparation of this new form of coded output is nearly complete.

A number of services provided by CFO are described in the section on 'Services for marine activities'. Sea wave and swell forecasts for periods up to 48 hours ahead for the North Atlantic are required for international broadcast and for

use by the Meteorological Office ship-routeing service. The charts of forecast wave height and direction of movement are prepared by the Medium-range Forecaster with guidance from wave forecasting models which use the surface winds predicted by the octagon version of the 10-level atmospheric model. Since sea waves are largely determined by the past or present effects of the surface wind field, and because the Office has access to the most recent forecasts of the surface wind and has considerable computer resources, it is in a unique position to make operational numerical forecasts of the state of sea. Work has therefore continued on the development of these models and on methods for improving the numerical forecasting of the surface wind fields. In particular the fine-mesh wave and swell model has been improved by incorporating new parametrization of the wave-growth and wave-breaking processes. Extensive validation of this new model in both artificial and real wind situations has shown that it simulates the growth of a wind-generated sea in a much more realistic fashion than the previous version, while retaining the accuracy already established in the propagation of swell. Both of these characteristics are important for applications by the Regional Water Authorities to coastal flooding prediction, in which keen interest has been shown during the year, particularly since the flooding of Portland in February by a long swell generated well out in the Atlantic. The programs have been made more general so that new geographic areas can be modelled with the minimum of delay. This facility was tested when support was given at short notice to the Ship Routeing bench for the tow of a dry dock through the Mediterranean Sea. Interest in the archived model results has increased this year as a supplement to the observational data for seas around the United Kingdom. In particular the data stored twice a day during 1978 is now being used by the Wave Energy Project to investigate the potential for obtaining energy from sea waves around various parts of the country. The Branch continued to operate a storm-surge prediction model produced by the Institute of Oceanographic Sciences at Bidston for the Storm Tide Warning Service. The model ran satisfactorily throughout the storm season which finished in April and was re-started in August for the 1979/80 season. Consideration has been given to the use of finer-mesh surge models, also written at IOS, for the prediction of tidal conditions around the west coast of the country and also in the Thames Estuary.

The computer terminal facilities in CFO, used for monitoring and amending data, have been enhanced by the addition of a second alphanumeric visual display unit (VDU) and a silent line-printer. These terminals, together with the VDU used by the Telecommunication Branch, are now supported by software specially written for the purpose by the systems team in the Data Processing Branch and are independent of all other terminals in the Office. This has enabled the response time for the VDUs in CFO to be improved. The range of programs available to CFO through the VDUs has been extended and now includes some which simply display or print data and others which allow the forecaster to interact with a numerical forecast to reject, correct or create observations, and thus modify the analysis. Hard copy is directly available on the new printer.

The objective analysis scheme has been modified to increase the effect of satellite sounding data following the reception of observations from TIROS-N and NOAA-6. These observations have been shown to be more accurate than the VTPR data received from NOAA-5. Winds obtained from the Meteosat geo-

stationary satellite and wind and temperature information received from aircraft via ASDAR (Aircraft to Satellite Data Relay) have been incorporated into the objective analysis. The standard corrections which are applied to upper-level radiosonde reports of geopotential to account for the systematic differences between different types of sonde were revised during the year.

Under the second phase of a contract with Eurocontrol an analysis scheme has been devised to cope with high-resolution wind and temperature data from aircraft over north-west Europe. It is expected that in the future these data may be obtained from civil aircraft equipped with Aircraft Integrated Data System (AIDS). Data were collected from several aircraft during the week beginning 28 January 1979 and experimental analyses have been produced. Eventually it is intended that the aircraft will be interrogated from the ground and that the data will be transmitted and processed rapidly so that the resulting analyses may be used for short-period forecasts for air traffic control purposes.

Satellite image data (cloud pictures) have continued to make a valuable contribution to the preparation of surface and upper-air analyses, particularly over the North Atlantic and European regions. CFO are now receiving data from the two United States polar-orbiting satellites (TIROS-N and NOAA-6) both of which were launched during 1979. The satellites orbit at a lower height than the earlier NOAA-5 satellite (switched off in March) and give a somewhat smaller field of view at any time, but their superior image resolution and the shorter time between pictures more than compensate for this. Pictures from the European Space Agency geostationary satellite Meteosat have continued to be used in CFO. The frequency of these pictures, at hourly intervals or closer in some cases, proves useful for helping to confirm tentative conclusions from a subjective interpretation of an individual picture and for studying rapidly moving features.

One important routine function of the Central Forecasting Office is the issue of hourly forecast minimum regional pressure values which are used as aircraft altimeter settings (QNH) for a number of regions covering the United Kingdom. These enable national air traffic control centres to maintain safe aircraft separation in the vertical. Late in 1978 and also during 1979 the service was extended to include three new areas over the North Sea (Cormorant, Skua and Petrel). This forecasting is a difficult undertaking because of the paucity of observations received from the area but it has become necessary because of the very large number of helicopters now flying over the North Sea to and from the oilfields.

The computer support section of the Branch continues to spend considerable time on the maintenance of the operational suite of programs which is frequently having to be modified because of changes in the international codes and to station numbers, or because of changes to the COSMOS system. Every effort is made to make full use of the expanding facilities provided by the Computing Laboratory. In the last quarter of the year the work of this section has been increasingly directed towards the planning and programming of a large part of the suite of programs for running a new operational numerical forecasting model on the new computer when it is commissioned in 1981. The designing and programming of the 4-dimensional data assimilation scheme and the basic numerical prediction model are the responsibility of the Forecasting Research Branch, but the Central Forecasting Branch is responsible for those parts of the suite dealing with the assembling of observational data, the monitoring of data,

the intervention processers, the output of products for operational purposes, and verification and archiving. The use of a new numerical model covering a wider geographical area than the present one, and using both sigma co-ordinates and a 4-dimensional data assimilation process, means that there will have to be much replanning of the work of the Intervention bench in CFO.

A comparative study of the numerical forecast models has been carried out by the Office for the Global Atmospheric Research Program (GARP). With the GARP Basic Data Set as their starting point, a total of 21 forecasts were made in seven centres in five different countries. Out of the five operational models in the study, the 10-level coarse-mesh model had the best performance. The Office has also been sending results of the numerical forecasts on magnetic tape to the Finnish Meteorological Service throughout 1979 for comparison with numerical products from other centres as part of the WMO Numerical Weather Prediction Project.

The daily tabulations for the *Daily Weather Report*, the *Monthly Summary* and the *Daily Aerological Record* continue to be produced by the two Datamatic typewriters controlled by paper tape. Although programs for automating the plotting of the published charts has already been developed, manual plotting has had to continue in the absence of a medium which makes a suitable replacement for the waxed stencils used for both the tabulations and the charts.

Members of the Branch serve on the WMO Working Group on the Global Data Processing System (one of the working groups of the Commission for Basic Systems) and on the Regional Association VI (Europe) Working Group on Co-ordination for Data in GRID Code Form.

Services for industry, commerce and the general public

Public services are provided by the Meteorological Office in two ways. Forecasts are available in almost all daily newspapers, are regularly broadcast on both radio and television and for the cost of a telephone call any member of the public can be connected either to the Automatic Telephone Weather Service (ATWS) or directly to a forecaster at one of the meteorological offices listed in the front of every telephone directory. On the other hand, there is a considerable demand for more specialized services and these are offered on a strictly commercial basis. During 1979 particular efforts were made to increase this revenue with the successful results recorded in the Administration section of this *Report*. In a climate of staff economies these efforts inevitably meant that an increasing proportion of staff time was devoted to revenue-producing services at the expense of free discussion by telephone with the public. However, there has been no diminution of services freely available via the mass media and by the end of the year more broadcasts were being made as a routine than ever before.

During the periods of snow and low temperatures in the early months of the year, the weather became a topic of considerable public interest. By invitation, not only the London Weather Centre (LWC) weathermen but forecasters at public service offices in many parts of the country gave live broadcasts and interviews in news programs on national, regional and local radio and on television. In particular, the national television forecasters appeared as part of the main evening news program on BBC 1 and were able to show satellite pictures. These were very well received by viewers and the amount of favourable comment led the BBC to make live weather broadcasts with satellite pictures a regular daily

feature at 2125. This innovation was greatly welcomed by the Meteorological Office because a presentation at peak viewing time had been sought since the earliest days of weather broadcasts on television.

As well as being visually attractive, there is no doubt that satellite pictures have really captured the public imagination, bringing the astronaut's view from space into the sitting-room. Moreover, they have led to much greater general understanding of weather patterns and the terminology used in weather forecasts. Viewers can now see for themselves such things as the masses of cloud associated with vigorous frontal depressions and the patchy nature of shower activity in polar airstreams. The early display methods were undeniably crude and development work was carried out by both the Office and the BBC to improve presentation techniques. As part of a reorganization of program schedules on BBC 2 the live broadcast during the early evening was dropped, but towards the end of 1979 a completely new style of television weather forecast was under development. The Office was invited to provide a regular part of a new late-evening news and current affairs program, making use of sequences of satellite pictures and new graphic techniques. In the future this program will be fully supported by a graphic computer and there are exciting possibilities for illustrating the movement and development of weather systems in ways never before available.

The weather outlook for the coming week given as part of the 'Farming' program on Sundays continued to be well received and this has now been supplemented by an updated forecast for the next four days broadcast at lunch-time on Wednesdays. A further interesting development was a move to introduce live weather presentations on BBC Regional Television. Towards the end of the year, forecasters from Nottingham Weather Centre started broadcasts on Friday evenings on BBC TV (Midlands). Other BBC Regions expressed a keen interest in the idea but staff availability has meant that progress could not be as rapid as might have been hoped.

It was perhaps fitting that these major advances in television weather presentations took place in the year which saw the 25th Anniversary of the first broadcast by a professional forecaster on BBC Television. This event took place in January and was marked by a very well-attended Press conference at the BBC Television Centre and widespread coverage in daily newspapers. The BBC arranged a special program on 'Nationwide' and all but four of the 25 weathermen (including one lady) who have presented the forecasts during the 25 years were able to attend and take part.

Services were also provided for commercial television. In most cases scripts were supplied to be read by an announcer, but facilities for obtaining information were made available to three companies which employ a professional forecaster. Satellite pictures also appeared during the year on commercial channels.

Whereas 1979 was a year of significant changes on television, radio broadcasts altered little in character but increased in number. By the end of the year, no less than 18 local or VHF regional radio stations throughout the country included live broadcasts by forecasters at public service offices. Scripted forecasts were supplied to many more stations. In addition to the routine broadcasts and the many interviews given about newsworthy current weather, occasional contributions were made on a variety of topics. A selection of these is included in Appendix II (page 150).

Calls made to the Automatic Telephone Weather Service (ATWS) continued to grow at a remarkable rate reaching the total of 30 805 870 in 1979 compared to 24 467 679 in 1978 and 19 040 617 in 1977. In response to this clear evidence of expanding public demand, further efforts were made to improve the service to the public. Discussions with the Post Office sought both a reorganization of the forecasts available at the various service centres and an extension of the service to cover the whole of England and substantial parts of Wales, Scotland and Northern Ireland. It may take several years to achieve, but the aim is that eventually a caller in any part of the United Kingdom should be able to listen to a recorded forecast for his locality for the price of a local call.

The Office continued to supply information for the teletext services on the BBC (Ceefax) and IBA (Oracle). Involvement with the Post Office Viewdata system, Prestel (see Plate VIII), increased, although the system has not developed as quickly as had been predicted by either the Post Office or the television industry. A shortage of sets meant that the market trial covered a much smaller sample than had been envisaged and the public service did not start until the autumn and then for London only. However, the meteorological data base provided for the system was further expanded, and plans were completed for the automatic insertion of weather reports by high-speed data transfer directly from the computer at Bracknell to that of the Post Office in London. This will save a great deal of manual input and will be brought into use as soon as the Post Office computer can accept information in this form.

Despite the increasing amount of general weather information provided for the public, the total number of enquiries, routine and casual, dealt with at public service offices continued at a high level. For example figures over the past three years at the six Weather Centres were as follows:

	London	Manchester	Glasgow	Newcastle	Southampton	Nottingham
1977	307 539	132 659	109 640	99 144	109 700	65 019
1978	306 993	164 290	123 077	109 988	106 220	71 306
1979	312 908	149 338	112 524	110 840	108 468	69 616

Grand totals: 1977, 823 701; 1978, 881 874; 1979, 863 694.

Specialized services have been available on a commercial basis from public service offices for many years and are described in the free brochure 'Weather Advice to the Community' which also lists all the telephone numbers to which enquiries may be directed. Some of these services were developed to meet the needs of large industries. The most important of these in revenue terms is the offshore industry which is serviced from the London Weather Centre and from the forecasting offices at Aberdeen, Kirkwall and Lerwick, which are closer to the centres of activity. A fuller account is given under 'Services for marine activities'. Also of considerable importance are the services to the gas and electricity industries to assist in demand prediction and those to highway authorities as an aid to gritting and salting of roads. The need to conserve energy has led to an increased demand for the standard temperature-prediction service, whilst forecasts of dry spells for farmers and of weather for pigeon-racing clubs were also in demand.

Apart from these major examples of customer interests in common for which a standard service is appropriate, the forecast requirements of other users are so varied that it is difficult if not impossible to design a service to suit everyone.

During 1979 a much more flexible approach was adopted and particular efforts were made to develop consultancy services. The basis of these is that a customer is given an ex-directory telephone number on which a forecaster may be consulted without delay to discuss the particular matters of operational concern to the caller; charges are based on the complexity of the information sought. The number of customers who registered for a service of this kind suggests that the idea will become popular.

The pressure to increase revenue led to a continuing effort to publicize and demonstrate the ability of the Office to make a cost-effective contribution to industrial and commercial activities. During 1979 the Ministry of Defence Directorate of Promotions and Facilities (DPF) together with the Central Office of Information (COI) designed and produced major stands at four exhibitions. These were at the Horticultural Exhibition in Brighton during April, the Royal Agricultural Show at Stoneleigh in July, and both the Offshore Europe Exhibition at Aberdeen and the Southampton Boat Show in September. As well as being of commercial benefit, these stands provided extremely useful exercises in public relations. The Office contribution was in each case co-ordinated by the Public Services Branch, but members of staff from many branches assisted with both material and personnel to man the stands. For example, at Aberdeen there were demonstrations of forecasting and climatological services, marine instrumentation, ship routeing and automatic weather stations. Needless to say sophisticated communications were essential to the success of this display.

In addition to the major stands sponsored by DPF, the Office from its own resources mounted displays at no less than 14 other exhibitions during the year. The Cartographic Section prepared display boards of a high standard and, under the general co-ordination of the Public Services Branch, other branches contributed appropriate expertise. Of particular note were the highly successful displays mounted in the main shopping centres at Glasgow and Edinburgh early in the year. Apart from exhibitions, the Office also publicized its services by limited advertising in selected trade journals and no opportunity was lost to obtain free publicity by responding to invitations for articles in journals and newspapers. The brochures 'Weather Forecasting Today', 'Hydrometeorological Services', 'Weather Advice to the Community', 'Offshore Weather Services' and 'Services for Shipping' were all revised and re-published during the year.

The demand for visits by societies, schools and universities continued unabated, and before the end of the year applicants had to be told that visits to Bracknell could not be arranged before 1981 because dates were fully booked for 14 months ahead. Visiting parties were also accepted at Weather Centres. Staff members gave many lectures, most of them in their own time on a voluntary basis, to bodies of all kinds from Church Groups, Women's Institutes, Rotary, and schools to universities and national institutions. A small selection of these lectures is listed in Appendix II (page 150). The Public Services Branch and public service offices including Weather Centres also dealt with a vast amount of correspondence, much of it from the general public or from schools, and handled many enquiries from the Press, radio and television. The hard winter weather early in the year, the visit of His Royal Highness the Prince of Wales to Bracknell in June, and the Fastnet Race disaster in August, all led to notable peaks of public interest in the weather and the Meteorological Office.

Services for the general public (overseas)

The meteorological office at RAF North Front, Gibraltar, provides meteorological services for the Gibraltarian general public through the media of Press, radio and television, and for various civil departments and engineering and commercial concerns, including oil exploration companies working off the Moroccan coast. Similar services were provided from the meteorological office at RAF Luqa, Malta, up to the final withdrawal at the end of March. In Cyprus, services to the general public from the meteorological office at RAF Akrotiri are limited to forecasts broadcast by the British Forces Broadcasting Service. A similar service for BFBS in Germany was provided from the meteorological office at the Headquarters of Royal Air Force Germany, Rheindahlen. The services are provided in accordance with charging policies for similar services in the United Kingdom.

Services for marine activities

The extraction of oil and gas from the sea areas over the continental shelf has necessitated both capital investment on a massive scale and a wide range of activities including surveying, drilling, platform construction, towing, installation and fitting out of huge structures, pipe-laying, diving and operation of tanker terminals. Most of these activities are highly weather-sensitive and, as the waters around the British Isles can be a very hostile environment, it is not surprising that the overall demand for forecasting services remained at a high level. However, whereas 1978 saw the introduction of new types of service including the deployment of forecasters offshore and in support of the major tanker terminals in the Orkney and Shetland Islands, 1979 was a year of consolidation rather than innovation.

The Meteorological Office has provided specialized services for the offshore oil and gas industry since exploration in the North Sea began in the mid-1960s. London Weather Centre (LWC) is responsible for this work and throughout the year a team of experienced staff provided forecast and warnings services 24 hours a day on a commercial basis. The team had full support and advice from CFO and, by means of facsimile and teleprinter links, was supplied with up-to-date pictures from the polar-orbiting and geostationary meteorological satellites, forecast charts for periods up to 5 days ahead and with output from the COSMOS computer complex including detailed charts of wind, waves and swell over the continental shelf. The quality of any forecast depends, in part, on the density and reliability of the weather observations on which the initial analysis is based and during 1979 considerable effort was devoted to the improvement of the reporting network from the North Sea. To this end, discussions were held with various government departments and the United Kingdom Offshore Operators Association (UKOOA) and useful progress was made.

With the aid of good communications including Telex, document facsimile and radio-telephone, forecasts and warning services for the majority of operators are provided by LWC directly to shore bases or to the installations. However, the organization has been developed so that services can be channelled through a forecaster at or near the centre of operations when this is preferred by the customer. Thus, with full back-up advice from LWC, forecasters based at Aberdeen/Dyce Airport can give face-to-face briefings in Aberdeen to operators based there who request this facility. Similarly, forecasters at Kirkwall and Lerwick provide full services locally to meet the needs of the Orkney and

Shetland Islands port and harbour authorities and the oil companies concerned with the operation of the tanker terminals at Flotta and Sullom Voe respectively.

In addition to the services for point locations, LWC provide forecasts for tows of rigs and structures on request: for example, the tow of a rig jacket from Cherbourg to the Tartan Field off north-east Scotland and the subsequent pipe-laying operation to connect the Field to the terminal at Flotta. The major event of this type during 1979 was the tow, from Ardersier near Inverness to the Murchison Field north-east of Shetland, of a jacket which weighed well over 25 000 tonnes, was 165 metres high and was the largest steel structure ever to be launched from a barge (see Plate III). A temporary forecast office was set up at the construction yard and, with full support from LWC, forecasts were issued to cover the float-out period and the tow of 335 nautical miles. A forecaster was then transferred by helicopter to the semi-submersible crane vessel *Balder* which served as the control centre for the jacket installation. During the days that followed, relays of forecasters from Aberdeen Airport were air-lifted to the *Balder* to cover critical stages of the construction, such as the jacket launch, up end and module support frame installation. Meanwhile, special forecasts were provided by LWC for the tow of various modules first to Bergen and then to the Murchison Field from places as far apart as Bordeaux, Zwijndrecht in Holland, Middlesbrough, Newcastle and Burntisland in Fife.

During 1979, increasing interest has been shown by several operators in the new type of forecast presentation in terms of exceedence or otherwise of operationally significant thresholds which LWC has been developing. This is but one facet of LWC's continuing liaison with the offshore oil and gas industry, maintained not only by personal contacts but also by meetings of the Technical Advisory Group set up by the Oceanographic Committee of UKOOA and also of a subcommittee of the Oil Industry International Exploration and Production Forum. A major stand was manned at the Offshore Europe '79 Exhibition at Aberdeen in September which attracted wide attention.

Services to shipping via BBC Radio, the Post Office coastal radio stations and our international radio-teleprinter and radio-facsimile broadcasts continued throughout the year. Since the reorganization of BBC wavelengths late in 1978, the forecast for Inshore Waters at 0020 on Radio 4 has immediately followed the Shipping Forecast on the same channel. Early in 1979 the opportunity was taken to eliminate the overlap in the coastal reports broadcast with the two forecasts; the most important change was the introduction in the Shipping Forecast of reports from the Channel Light-vessel in place of those from Portland Bill – the latter being retained in the reports broadcast in the Inshore Waters forecast. During the year the Post Office continued its expansion of coastal VHF radio stations. This program commenced in 1966 with the addition of VHF radio facilities at the then existing eight medium-frequency coastal radio stations and has since been continued with the establishment of 'slave' stations in the form of unmanned VHF stations remotely controlled from the relevant medium-frequency coast radio station. These facilities provide a similar service in the way of weather broadcasts transmitted simultaneously with the medium-frequency broadcasts from their controlling master station. In 1979 VHF 'slave' stations were established at Islay, Skye and Lewis. Requests via radio-telephone from ships at sea for forecasts are still handled by CFO, who also continue to issue gale and storm warnings for waters around north-west Europe and eastern North Atlantic as far as 40°W.

The needs of fishermen and yachtsmen for up-to-date local weather information relating to inshore waters has been recognized by the broadcasting authorities and during the year more forecasts of this type were broadcast than ever before by both BBC and independent radio stations. These local forecasts were prepared by regional offices and, in particular, by Southampton Weather Centre which has continued to specialize in providing information for yachting and inshore marine activities. In support of forecasts many charts were issued by hand and by document facsimile, notably during Cowes Week. Special forecast services were provided for the Admiral's Cup and the Half Ton World Championship. A full investigation was made of the meteorological situation during the period of the Fastnet yacht race and this information, together with details of forecasts and warnings issued, was passed to the Royal Yachting Association to assist with their enquiry into the tragic events which marred the race (see Plates I and II). The degree of public interest and concern about this led to special broadcasts on both radio and television by Meteorological Office staff. Following the Fastnet Race, there was a very significant increase in calls to Southampton Weather Centre by yachtsmen and the number of enquiries answered during August was more than 40 per cent above normal. The Meteorological Office again participated in the Southampton Boat Show and the stand attracted large numbers of visitors; the real-time satellite pictures received by facsimile on the stand were a focus of interest and the staff in attendance were kept in almost continuous discussion.

Document facsimile was used increasingly in 1979 both to communicate between offices such as LWC and Aberdeen and to send information in chart form to customers. An important innovation during 1979 was that HM Coastguard installed facsimile receivers in each of their Regional Rescue Centres and both actual and forecast charts and sea area forecasts are now sent twice daily to all Centres by regional forecast offices.

Forecasters were again present on board the trawler support ship *Miranda* which was located off the coast of northern Norway from late November 1978 to mid-April 1979. The forecasters were supported by guidance forecasts and advice from CFO and were able to maintain close liaison with the British fishing fleet in the area, issuing regular local forecasts and warnings of both gales and ice accretion as necessary. In addition, the meteorological office at Pitreavie continued to provide a winter forecast service for the benefit of North Sea fishing vessels. The forecasts issued covered a 72-hour period and were broadcast daily from October to April.

Forecasts for ships of the Royal Navy were supplied by the Pitreavie and Plymouth meteorological offices, and the Aberporth meteorological office provided support for Royal Navy ships undergoing trials in Cardigan Bay. Royal Air Force marine craft at home and abroad were provided with forecasts by the nearest meteorological office. Up until our military withdrawal from Malta at the end of March, information was provided to the engineers constructing a breakwater at Marsaxlokk.

Oil slicks and pollution at sea are emergencies in which CFO plays its part in issuing forecasts and guidance advice. CFO also works closely with the officers of the Storm Tide Warning Service who are responsible for issuing alerts on occasions when unusually high tides caused by strong winds give rise to the risk of flooding on the east coast of England.

A ship-routeing service is provided to advise on North Atlantic and North

Pacific passages and to offer advice in regard to the movement of tows and salvage operations. Advice is also given to vessels on passage in other parts of the world on request and this year the service was extended to the southern hemisphere to advise vessels trading between Australia and South Africa and also to two very large crude-oil carriers sailing from the United Kingdom to Panama via Cape Horn as they were too large to transit the Panama Canal.

The object of the service for conventional vessels is to select the best route for the ship to follow in order to reach her destination in the shortest possible time with the most economical fuel consumption commensurate with the least damage to ship and cargo. To achieve this, data are extracted from the ship's deck logbook to determine the vessel's response to various sea wave fields and a ship/wave performance curve is constructed. However, the service has now amassed a large amount of performance data for almost all types of vessels and it is frequently possible to assess wave/speed characteristics from basic ship size and type information without recourse to the deck logbook. The forecasters of CFO provide the ship-routeing officers, who are all Master Mariners with long sea-going experience, with wind and sea predictions up to 72 hours ahead at 12-hourly intervals and this information is used with the performance curve to determine the most favourable course for the vessel to follow. Subjective consideration is also given to the loading state of the vessel, navigational hazards such as shoals, sea ice and areas of fog and also to sea-surface currents. The later stages of the voyage are also borne in mind. Communication with the vessel to be routed is usually by Telex prior to sailing and via predetermined coastal radio stations whilst on passage.

Routeing advice to tows which do not have restrictive weather parameters is similar to that provided for conventional ships but allowance is made for the slower speed of the tow and for restricted manoeuvrability. For tows with limiting weather factors—which may be wave height or period, amount of heel or wind force—the routeing service advises when and where to seek shelter or when to resume passage.

During the year the number of routeings, including tows and salvage operations, increased by 72 per cent. As a result of advertising, the ship-routeing service has become more widely known in world shipping circles and more foreign-flag vessels are using the service, including some of American, Canadian and Egyptian nationality. In January and February the service provided weather and wave data together with advice as to a suitable calm sea area where the oil tanker *Andros Patria*, damaged and leaking oil owing to an explosion on board, could safely be discharged prior to being towed to harbour for repairs. Also, the service advised on the towage of the floating dry-dock *Ataka* from Norway to Egypt (see Plate VI). This dry-dock was of special construction, consequently placing severe limitations on the weather conditions in which it could be moved.

Services for civil aviation

Responsibility for civil aviation in the United Kingdom rests with the Civil Aviation Authority (CAA). Professional advice needed by CAA on meteorological matters is given by the Meteorological Office which also provides meteorological services on a repayment basis. During the past decade, the pattern of civil aviation has changed and, as noted in earlier *Reports*, a Meteorological Review Committee was set up jointly by the CAA and the Ministry of Defence in 1977 to examine the current requirement for meteorological services for civil aviation.

Representatives of the users were nominated by the British Civil Aviation Standing Conference and the Meteorological Office participated. Having obtained the views of airlines, general aviation and helicopter operators, a Statement of Requirements agreed by all interested parties was prepared and promulgated during the summer of 1979. The most important innovation in the Statement concerns the briefing of aircrew. Access by telephone to a forecaster is still considered necessary, but face-to-face briefing and such aids as closed-circuit television are now designated as desirable rather than essential for safe and economic civil flying. In the light of this Statement, the CAA and the Meteorological Office started a joint review of meteorological services and facilities at individual airfields to determine how the Requirements may be met in the most cost-effective manner.

The cost of aviation fuel has escalated and the need to economize is greater than ever before. Major airlines operating long-haul routes have found significant financial advantage in centralized flight planning. Amongst the many routine products from the COSMOS computer at Bracknell are forecasts of upper winds and temperature at ten levels up to 100 mb (53 000 ft≈16 000 m). This information can readily be provided in grid-point format suitable for direct input into flight-planning computers and a service of this kind has been supplied to British Airways for several years. During 1979 there were several discussions with British Airways about future development of this service, other operators expressed interest and a talk was given at Bracknell to a visiting party representing European airlines. Working papers on the subject were also prepared and endorsed by CAA for presentation at the forthcoming meeting of the International Civil Aviation Organization (ICAO) Area Forecast Panel.

The Principal Forecasting Office (PFO) at London/Heathrow Airport is designated by ICAO as the Area Forecast Centre responsible for flights from any departure airfield in Europe across the Atlantic to Canada and the USA. COSMOS output, modified to include detail of the structure and position of jet streams by a team of specialist upper-air forecasters in the Central Forecasting Office (CFO) at Bracknell, is passed to PFO Heathrow. With the addition of significant-weather charts prepared by aviation forecasters at Heathrow, the upper-air charts from Bracknell are distributed widely throughout Europe by land-line and radio-facsimile. As an Area Forecast Centre, PFO Heathrow also originates warnings of significant weather hazards (SIGMET) for aviation over a large area covering most of England and Wales and well out into the Atlantic; special SST (supersonic transport) SIGMET messages are prepared to cover Concorde operations. The Main Meteorological Office (MMO) at Prestwick has a similar responsibility for flights over Scotland and Northern Ireland.

Reliable weather observations are needed at all airfields. Wherever possible, hourly or half-hourly reports (METARs), and special reports when significant changes occur, are made by Meteorological Office staff, but at many non-State airfields observations have to be made by Air Traffic Control Assistants (ATCAs) who are specially trained and certified for this work. The demand for observer training of ATCAs increased during 1979. Four one-week courses were held at the Meteorological Office College and the students were then attached for a further week to an observing office manned by Meteorological Office staff. Certificates are only issued on the recommendation of Principal Meteorological Officers following successful completion of a further period of observing duties under supervision at the ATCA's home airfield.

Operational meteorological (OPMET) data consisting of terminal aerodrome forecasts (TAFs) and METARs are exchanged rapidly within the United Kingdom using CAA teleprinter circuits centred on the Heathrow message switch. A similar exchange between airfields in Europe and the Mediterranean area is achieved using a dedicated teleprinter network (MOTNE) and the material is also stored in special OPMET data banks at Brussels and Vienna. During 1979, increasing use was made by smaller airfields and individual operators of the facility whereby limited selections of OPMET data can be received as a routine from the Heathrow switch on Aeronautical Fixed Telecommunication Network (AFTN) circuits. Irregular needs can be met by using the AFTN to interrogate the OPMET data banks.

The information originated by PFO Heathrow as an Area Forecast Centre is distributed within the United Kingdom by means of the civil aviation meteorological facsimile broadcast (CAMFAX). The charts are then photocopied as necessary at local airfields, and together with copies of OPMET data provide documentation for flights. Increasing use was made during the year of self-briefing facilities, but face-to-face briefing was provided at many airfields. These arrangements, supplemented by VHF broadcasts of METARs and short-period landing forecasts for aircraft in flight, met the requirements of scheduled and other services operating in controlled airspace, that is, above about 5000 ft.

The term 'general aviation' is used to cover air taxi services, executive aircraft, crop spraying flights and a wide range of private flying, ballooning, gliding and hang-gliding. The majority of these flights are below controlled airspace, and many of them use very small airfields. Special arrangements have to be made for their meteorological support. Pilots can contact aviation forecast offices in person or by telephone, to obtain detailed flight forecasts and briefings. Alternatively, information can be obtained from the General Aviation Visual Flight Forecast Service. From brief forecasts of flight conditions for each of 21 defined areas covering England and Wales, a pilot can assess whether flight under visual flight rules is possible. The forecasts, supplied by PFO Heathrow and MMO Manchester, are recorded and may be heard by dialling particular public telephone numbers. Similar arrangements are in operation in several European countries and forecasts to cover long-distance low-level flights can be obtained by international trunk dialling. Considerable interest was shown during the year in the possibility of providing a meteorological service for general aviation using a Viewdata system. A demonstration at Bracknell was attended by representatives of CAA and general aviation. Special frames of TAFs, METARs and flight forecasts were prepared and keyed into the data bank of the Post Office computer, Prestel, to demonstrate the potential of this method of information retrieval which could be used to call up meteorological or Aviation Information Service (AIS) information on to a specially adapted television set in a pilot's home, office or flying club.

Aviation activity in support of the offshore oil and gas industry has continued to grow. Helicopters operating to offshore installations require a specialized meteorological service in which particular attention is paid to low-level weather hazards. Forecasts for specific areas of the northern North Sea are prepared every six hours by MMO Prestwick. These are distributed widely to airfields concerned with North Sea operations and to some of the individual operators. The forecasting offices at Sumburgh (Shetland), Kirkwall (Orkney) and Aberdeen have borne the brunt of the heavy demand for advice and personal briefing, and

the allocation of a third forecaster to Sumburgh late in the year gave much needed relief to a very busy office. In November, the CAA extended the dedicated altimeter setting regions (ASRs) to cover the entire North Sea west of the median line; the addition of ASRs Petrel and Skua brought the total number of United Kingdom ASRs to 20 and forecast minimum pressures for each of these regions are prepared hourly at CFO Bracknell.

Work continued throughout the year on the plans to move PFO Heathrow from the Queen's Building to the Air Traffic Control Tower. The scheme was approved by the CAA Capital Projects Board and is scheduled for completion in 1981. Plans for the supply of a minicomputer and peripheral equipment were completed and contracts were placed for delivery to Bracknell early in 1980 for proving trials. As the new accommodation at Heathrow will not be available when the equipment is moved there from Bracknell, arrangements have been made to house it in a temporary building to be positioned near the Queen's Building. When fully operational, the automated equipment will provide many of the charts hitherto plotted manually. During 1979, a computer program was developed by the Special Investigations Branch in conjunction with PFO Heathrow to provide an analysis of all North American upper-air ascents in chart format. As an interim measure this program has been run on COSMOS and transmitted to Heathrow by facsimile. Quiet teleprinters were also installed at a number of working positions in the Heathrow office, each with its own designated broadcast appropriate to the position and controlled by the communication computer at Bracknell.

At the end of March, CAA withdrew services from Bournemouth Airport (Hurn). The importance of Hurn as a reporting station in the Basic Synoptic Network warranted the maintenance of an observing office on the airfield. As a result of successful negotiations with the Bournemouth Airport Authority, the existing office was retained pending the provision of new accommodation in the Control Tower. From April, forecasts for Hurn were prepared at PFO Heathrow. Late in the year the busy forecast office at Aberdeen/Dyce Airport was moved to greatly improved accommodation in the new Control Tower. At Birmingham, in order to bring the AIS office on to the same floor as the forecast office, CAA set in train a reconstruction of the accommodation. The resultant meteorological office, though smaller than hitherto, was designed to meet current requirements.

The year 1979 was very busy for international matters affecting civil aviation. The Meteorological Advisory Group (METAG) of the European Air Navigation Planning Group of ICAO set up a Working Group to develop operational requirements and planning criteria for meteorological services. The Group met three times in Paris and, after the subsequent meeting of METAG during September, a new Working Group was set up to consider methods of application. A member of the Meteorological Office attended these five meetings as a member of the UK delegation. In November he also attended a planning meeting in Geneva of the WMO Working Group for Provision of meteorological information before and during flight (PROMET). Another member of staff attended a meeting in Paris of the Working Group concerning meteorological services for International General Aviation (METSIGAG). Technical papers were presented at the CAeM Technical Conference on Aviation Meteorology held in Geneva during November. At the invitation of CAA, technical liaison visits were made to the French and German Meteorological Services to examine

their procedures for supply of information to aviation. As noted earlier, a considerable amount of work was also undertaken in preparation for the Area Forecast Panel which has been set up by the Air Navigation Commission of ICAO; the first meeting of the panel will be in Montreal during January 1980.

Services for civil aviation (overseas)

Services for civil and general aviation were provided from the meteorological offices at RAF North Front, Gibraltar, at RAF Wildenrath and RAF Gütersloh, Germany, and at RAF Luqa up to the final withdrawal from Malta at the end of March 1979. The meteorological office at the civil airport at Luqa is now manned by Maltese forecasters and assistants trained by the Meteorological Office under the 1972 Agreement with respect to the Use of Military Facilities in Malta.

Services for the Royal Air Force

Senior officers of the Meteorological Office continue to fill the posts of Chief Meteorological Officers on the Air Staffs at Headquarters Strike Command and at Headquarters Royal Air Force Germany. The Chief Meteorological Officers act as advisers on meteorological matters to the Air Officer Commanding-in-Chief Strike Command and to the Commander-in-Chief Royal Air Force Germany and are responsible for the organization of meteorological services to meet the needs of the Royal Air Force.

Meteorological services for the Royal Air Force in the United Kingdom, including the RAF units at the MOD(PE) airfields at the Royal Aircraft Establishments at Farnborough and Bedford and the Aeroplane and Armament Experimental Establishment at Boscombe Down, continued to be provided by offices which are organized largely in conformity with the RAF Group organization. The provision of services for the Royal Air Force in Germany continued unchanged. The Main Meteorological Office at the Headquarters of Royal Air Force Germany, Rheindahlen, supports subsidiary forecast offices at the RAF airfields at Wildenrath, Brüggen, Laarbruch and Gütersloh and the Army Air Corps at Detmold. The staff of the meteorological offices in Germany were fully involved in NATO evaluation exercises and invariably achieved high markings.

The Principal Forecast Office at Headquarters Strike Command, continuously manned by senior forecasting staff, is responsible for the technical control of the output from the subsidiary forecast offices at all the airfields in Strike Command and at several airfields in RAF Support Command. The resources in the Principal Forecast Office allow the subsidiary offices to meet the requirements of military aircraft operating in widely differing roles. Work continued on the extension of automated methods of working to the Principal Forecast Office and the development of automated support for the forecasters at the subsidiary offices with the aim of achieving greater efficiency and flexibility in responding to the requirements of the Royal Air Force. It is planned to introduce a minicomputer system into the Principal Forecast Office in 1980. The powerful computer system at Bracknell continued to provide major support to the offices serving the Royal Air Force in the United Kingdom and overseas through the automated selection and transmission of large amounts of data and the provision of forecasts for periods beyond about 18 hours ahead.

Main Meteorological Offices, also manned 24 hours a day, are located mainly at RAF Group or Maritime Air Region Headquarters. The location of the Main Meteorological Offices within separate regions of the United Kingdom allows expertise in regional meteorology to be applied not only to services for Defence but also for civil and general aviation and for the general public.

At the subsidiary forecast offices on airfields a forecaster is on duty at times determined by the local Royal Air Force requirement and outside those hours the forecasting responsibility is assumed by the parent Main Meteorological Office. Many of the subsidiary offices serving the Royal Air Force also provide services for civil and general aviation and for the general public from within the resources necessary to meet the Defence need.

The major part of the routine support provided for the subsidiary offices by the Principal Forecast Office at Headquarters Strike Command and the Main Meteorological Office at Headquarters No. 38 Group is in the form of a comprehensive six-hourly program of area and route forecasts in chart form which is transmitted by facsimile to subsidiary forecast offices. The broadcasts are designed to cover most of the routine operational requirements of the Royal Air Force in the United Kingdom. A dedicated teleprinter broadcast from the Principal Forecast Office allows a continuous flow of actual and forecast data related to the requirements of the Royal Air Force to be transmitted to the subsidiary offices where the personal briefing of aircrew and operational staffs and the provision of shorter-period subjective forecasts is considered by the Royal Air Force to be an essential service.

Mobile meteorological units, provided by the Tactical Communications Wing of No. 38 Group and manned by Meteorological Office staff in uniform, continue to support the Royal Air Force in the field and participate in exercises. Each unit has its own air-transportable sets of instruments and communication equipment for use in remote locations, including radio-teleprinters and radio-facsimile recorders and weather-satellite reception equipment. The staff who man the mobile meteorological units hold commissions in Class CC of the Royal Air Force Reserve of Officers.

A forecaster was again detached to Barksdale Air Force Base, Louisiana, to provide support to the Royal Air Force team participating in the United States Air Force, Strategic Air Command Bombing and Navigation Competition—GIANT VOICE 1979.

United Kingdom Defence requirements for meteorological support in the Mediterranean continue to be provided by the Main Meteorological Office at RAF Akrotiri and the observing office at Paphos in Cyprus and by the Main Meteorological Office at RAF North Front, Gibraltar. The office in Malta ceased to function as a Main Meteorological Office in October 1978 when RAF Luqa became non-operational and was reduced in status to a civil airport meteorological office manned by Maltese staff trained by the Meteorological Office. The office remained under the control of a senior Meteorological Office officer until the final withdrawal of the British military presence on 31 March. The first British meteorological office in Malta was opened at Pieta in 1922.

A routine program of radiosonde and radar-wind observations is maintained for the international upper-air network from the radiosonde unit at RAF North Front, Gibraltar. The obsolete Meteorological Office Mk 2B radiosonde was replaced by the Grawsonde from 27 February. The Grawsonde is also used for upper-air observations related to the local forecasting needs at RAF Akrotiri,

Cyprus, and a routine program of pilot-balloon ascents is maintained from the observing office at Paphos.

The VOLMET voice broadcast of plain-language reports from a selection of RAF airfields continued to be provided from the London military Air Traffic Control Centre at West Drayton. Some staff reductions in the meteorological office at West Drayton were made during the year as a result of the transfer of some of the responsibilties of the office elsewhere and plans were made to transfer the remaining work in support of VOLMET to the Principal Forecasting Office at Headquarters Strike Command. Consideration is being given to the eventual complete automation of the supply to West Drayton of data for the VOLMET broadcast direct from the automated communications centre at Bracknell.

The Office meets the requirements of the Royal Air Force for training in meteorology by the provision of lectures and tutorial assistance, mainly at the Support Command training airfields where young aircrew receive their first experience of meteorological support for their tasks from Office staff.

The first of a regular series of courses on Defence Meteorology for Meteorological Office staff was held in July with the aim of informing staff about to take up posts in military establishments about Defence matters and the role of meteorological services in support of military aviation. The course was held at the RAF Staff College, Bracknell, with the assistance of staff officers from the Ministry of Defence, Headquarters Strike Command, Headquarters RAF Support Command and the Directorate of the Army Air Corps. Training in briefing for military needs was an important feature of the course.

Services for the Army Air Corps

Meteorological services for the Army Air Corps are provided by subsidiary forecast offices at Netheravon and Middle Wallop, under the technical control of the Main Meteorological Office at Headquarters No. 38 Group Royal Air Force, and at Detmold in Germany under the technical control of the Main Meteorological Office at Headquarters Royal Air Force Germany at Rheindahlen. Although the offices serving the Army Air Corps are part of the larger Meteorological Office organization supporting the Royal Air Force, the services they provide are related entirely to the Army requirements.

The Senior Meteorological Officer at Detmold carries additional responsibilities as the Senior Meteorological Officer at the Headquarters of 1(BR) Corps at Bielefeld. Together with members of his staff he participated in exercises in the field and supported Harrier deployments from RAF Gütersloh.

Other services for the Army and Establishments of the Ministry of Defence Procurement Executive

Meteorological offices were maintained at the Royal School of Artillery, Larkhill, at the Royal Aircraft Establishment (RAE), Aberporth, and at the Proof and Experimental Establishments (PEE) at Shoeburyness, Eskmeals and Pendine. The office at Larkhill also provides meteorological support for the Chemical Defence Establishment at Porton and for RAE and PEE units located on Salisbury Plain. The office at Shoeburyness supports the Atomic Weapons Research Establishment at Foulness. The obsolete Mk 2B radiosonde system was maintained in use at Aberporth, Eskmeals, Larkhill and Shoeburyness throughout the year but will be replaced in 1980 by the Mk 3 radiosonde system

which has been specially modified to meet the requirements of the trials establishments for real-time, high-precision upper-air data.

Meteorological Office staff were attached to the Army practice camps at Sennybridge and Otterburn for several periods during the year to provide meteorological support for artillery firings and to the rocket range at South Uist in the Hebrides for a program of missile firings during the summer. Several Defence establishments were provided with meteorological data and advice connected with the development of weapons and military equipment and two lectures on meteorology were given to the Royal Military Academy at Sandhurst.

Liaison with the Royal Navy

Close co-operation in Defence matters was maintained with the Directorate of Naval Oceanography and Meteorology, mainly through the post of Naval Liaison Officer in the Headquarters of the Meteorological Office at Bracknell. Co-operation in the organization and development of national and NATO meteorological support between the Meteorological Office and the Royal Navy ensures an efficient across-the-board response to United Kingdom Defence requirements for meteorological support for land, sea and air forces both nationally and within NATO.

International defence services

The Meteorological Office participated actively, on behalf of the United Kingdom, in the work of a number of NATO groups concerned with the co-ordination of meteorological support for military needs and also contributed to studies associated with that support. The Assistant Director (Defence Services) continued as Chairman of the NATO Military Committee Meteorological Group for the 1979 meeting. The Meteorological Office took an active part in various NATO exercises, including the major biennial WINTEX exercise in March.

The Meteorological Office provided a Principal Scientific Officer for the post of Chief Meteorological Officer on the staff of the Supreme Allied Commander at SHAPE in the rank of Group Captain. The British contribution of three UK staff members was maintained at the NATO Allied Meteorological Office at Maastricht in Holland.

Services to the Home Office

Detailed plans for meeting the meteorological requirements of the United Kingdom Warning and Monitoring Organization were maintained and developed. Forecasting staff were provided for the meteorological cells in the five Sector Controls during the national exercise in May and the NATO exercise in October. The Meteorological Office provided the charts and data for the exercise weather used throughout Europe in the NATO-wide exercise. Lectures on the Meteorological Office organization related to fallout monitoring were given to Sector Control staff and to UKWMO continental liaison officers.

Services for nuclear establishments

Arrangements for Main Meteorological Offices to supply information to nuclear establishments of the United Kingdom Atomic Energy Authority, British Nuclear Fuels Ltd, AWRE and the Electricity Generating Boards in the event of the accidental release of radioactive or toxic material, were kept under constant

review and frequently exercised. Similar arrangements cover emergencies which could arise in the transport of radioactive material or which might involve nuclear submarines in port.

Climatological Services

The provision of advice on the climate of a location is an important part of the range of services offered by the Meteorological Office. Whereas forecasting advice is of benefit in the day-to-day running of weather-sensitive industries, the role of climatology is mainly at the planning and design stages, for example in the provision of probabilities of extreme wind events to assist in building design.

Climatological information can often be provided relatively cheaply with small demands on the Meteorological Office computer resources, but may be of considerable value to the customer. The backbone of the service is the large volume of observations made over a long period, but to this is added the scientific expertise to analyse and interpret the observations in a sensible manner.

Climatological data

The climatological network consists of over 600 stations and as can be seen from Table IV (page 78) the Meteorological Office itself runs fewer than a hundred. The remainder, run by private individuals and public bodies with an interest in the weather, provide a good indication of the variations in climate over the British Isles. In recruiting such stations, emphasis this year has been placed on the sparser parts of the network such as north and west Scotland. To assist the voluntary observers, training courses were held at the Meteorological Office College, Shinfield Park (near Reading), and at the Edinburgh office.

Each month the observations are sent to Bracknell, Edinburgh and Belfast, where the data collected over many years provide the main basis for dealing with climatological enquiries. The observations are also keyed for the computer and increasing use is being made of data in this form. Errors can arise at all stages and checks on the consistency of the data are applied, with reference back to the observers as necessary to resolve queries. The severe winter of 1978/79 gave rise to considerable additional effort in this area, since heavy snowfalls disrupted observational routines and made representative measurements of precipitation difficult.

The computer archive continues to grow as data for each new month are added, but there is a daunting backlog of historical data (mainly before 1959) which are only available in manuscript. For many climatological studies it is convenient for all the data for one station to be organized together. The computer archive of daily data in this form has been increased from 300 to 600 stations. Also an archive of mostly daily data, but including radiation and evaporation, has been constructed for about 100 stations primarily for agricultural investigations.

The automatic recording of observations is attractive, giving more continuous measurements in a form which can be readily absorbed into the computer archive, but it is not easy to achieve the necessary reliability. This year the first batch of operational Digital Anemograph Logging Equipments (DALE) have been installed for recording wind, and although a number of teething problems have been overcome further comparisons with conventional observations are

required. A more ambitious undertaking is the Automatic Climatological Recording Equipment (ACRE) to record a range of meteorological variables, with only weekly visits from a caretaker. Assessment of sites for the first ten (mostly in Scotland) is being undertaken while the prototype instrument undergoes trials. Handwritten upper-air returns for United Kingdom stations ceased during the year as recorded data from the Mk 3 radiosonde became available, though again there have been certain difficulties.

Land climatology

The number of climatological enquiries and the accompanying revenue have continued to rise. The enquiries are handled at Bracknell (for England and Wales), at Edinburgh (for Scotland) and at Belfast (for Northern Ireland). As usual they come in all shapes and sizes and the percentages relating to different applications are given in Table XIII (page 82).

Enquiries from the building and construction industry continue to be the major revenue earner, particularly in relation to inclement weather claims. In Scotland contact was established with the Scottish Committee of the Federation of Civil Engineering Contractors, in an attempt to publicize meteorological services to the building industry. The building climatology unit, funded by the Building Research Establishment, has been involved with the meteorological aspects of several projects including cavity-wall insulation, the natural ventilation of large buildings, the long-term weathering of concrete and frost damage to roads. Road damage was of special concern after the hard winter, and the Belfast office also gave advice on the problems of asphalt laying and 'frost after rain' damage to brickwork.

A growth area this year has been in connection with energy conservation and alternative sources of energy. One contract has been with Royal Dutch Shell who require 3-hourly temperature values for the whole of western Europe to help control the supply of domestic oil. Another was to provide Exeter University with wind information in various forms for studies on wind energy. Advice is not restricted to the United Kingdom and, while many of the overseas enquiries were again for building design (including heating and ventilation), an unusual one was concerned with wind data around the world at a height of about 2000 feet in connection with route planning for automated freight airships.

On the investigational side, studies were carried out to demonstrate the unreliability of certain published techniques for estimating once-in-fifty-year extremes from a few years' data and to analyse the climate differences between stations only a few miles apart in both Glasgow and Edinburgh. A major exercise is the revision of a *Climatological Memorandum* (No. 50A) on extreme winds for design purposes. This is well under way and is using data up to 1978 (as opposed to 1971 for the original version) and a refined method of estimating the parameters of the extreme value distribution.

The Climatological Research Group is mainly concerned with the spatial variation of climate which is important in attempts to advise on the climate of a locality when perhaps the nearest station is in different terrain. The use of statistical methods to determine characteristic patterns has been extended to 10 variables and by grouping stations (again objectively) the United Kingdom has been divided into regions. A spin-off has been a new quality-control technique which is being tested on routine data. Another study is attempting to model the variations of different elements in time and space (due to topography, latitude

and so on) so that relevant parameters of the distribution can be estimated for any location. Lastly the mapping of wind errors using optimal interpolation methods has proved a valuable technique in assessing the effectiveness of the anemograph network.

Marine climatology

The continuing heavy demands for marine climatological data and advice have led to an increase in staff in the marine climatology section. Although the majority of enquiries are concerned with the design and operation of offshore operations in the North Sea, the scope of the work is much wider. For example, assessments were made of the likelihood of recurrence of two incidents of severe weather: the floods at Portland on 13 February (due to large swell waves from a distant storm in mid-Atlantic) and the storm of 14 August which resulted in the loss of yachts participating in the Fastnet Race. Also, data are available on a world-wide basis and have often been supplied for more distant waters, including advice on weather likely to affect the tow of a semi-submersible vessel from Hiroshima to Aberdeen via the Indian Ocean, and for shipping operations on a route from north-west Australia to Japan.

With enquiries becoming more complex and detailed, it is important to carry out investigational work in parallel. A detailed study has been undertaken of the directional characteristics of strong winds and high waves for the North Sea, which vary with locality to a far greater extent than is generally appreciated. Research has also started into the problem of the simulation of wind and wave sequences for offshore areas to compensate for the lack of long-term continuous data in these regions.

For all this work it is very desirable to improve and extend the basic archive of marine data and the range of computer programs to process it for different applications. At the Offshore Europe '79 Exhibition held at Aberdeen in September some of the present computer facilities were demonstrated by accessing and analysing marine data via a terminal linked to the Meteorological Office computer in Bracknell.

Operational and climatological work on sea-ice continued throughout the year. Daily charts were disseminated by radio-facsimile broadcast and monthly charts for the northern hemisphere were published for climatological and research purposes. Advice on sea-ice matters was given, for example, for ship routeing and expedition planning. The sea-ice and ocean-current sections of the Admiralty *Pilots* are kept under review and six volumes were revised in 1979.

The marine climatologist remains active on the Working Group on Marine Climatology of the Commission for Marine Meteorology (CMM) of WMO. Revision of the extreme wind maps for offshore areas included in the Department of Energy's 'Guidance on the Design and Construction of Offshore Installations' has necessitated liaison with experts from France and Norway to harmonize environmental standards over the whole of the west European continental shelf. There has also been collaboration with the Institute of Oceanographic Sciences in the production of commercial reports and with the Hydraulics Research Station in the investigation of the connection between high water levels and strong winds in the Thames Estuary. One new venture has been the setting up of a joint study program with the National Maritime Institute. This is to establish the capability of meeting engineering requirements for wave climate data by methods designed to make the best use of existing archives held

by meteorological agencies validated as far as possible by comparison with available instrumental data.

Publications

The *Monthly Weather Report* dates back to 1884 and summarizes the observations made in the United Kingdom by both official and voluntary observers. It is published monthly though several months in arrears to enable most of the queries on the data to be sorted out. Another regularly produced publication is the annual *Snow Survey of Great Britain*, containing information on snowfall and the extent of snow lying. It was of particular interest this year after the severe winter.

An illustrated 20-page brochure entitled 'Scotland's climate–some facts and figures' was published to coincide with two major exhibitions held in Glasgow and Edinburgh in February on Public and Climatological Services Work in the Meteorological Office. The publication was intended primarily for teachers and students of environmental subjects, and has sold briskly over the remainder of the year. Work has now commenced on a new series of memoranda describing the climate of the different regions of the United Kingdom, and again the intention is to produce a limited amount of information in an attractive format.

After a long absence, the publication of *Upper-Air Summaries* has been resumed with the issue of a comprehensive series of tables for Stornoway covering the period 1961–70 (Met.O.910a). The tables were produced by computer program and similar parts for other stations will be available shortly, starting with Crawley and Lerwick. In contrast, the *Tables of Temperature, Relative Humidity, Precipitation and Sunshine for the World* have been painstakingly constructed by hand. The volume dealing with North America awaits publication, while about 60 per cent of the data has been compiled for the African volume.

Services for Hydrometeorology

The hydrometeorological services provided by the Meteorological Office depend for their continuation and development on the ready availability of good quality hydrometeorological data which must then be presented in ways tailored to the changing needs of a wide range of users. The primary task of the collection, quality control and archiving of rainfall data from a network of about 6500 rain-gauging stations continues. The majority of stations report daily rainfall totals though some report only monthly totals; at a smaller number of stations continuous automatic recording of rainfall is employed. The Edinburgh office administers and inspects stations in Scotland and the Belfast office carries out these functions in Northern Ireland. The Bracknell office has responsibilities for the remaining stations and holds the final rainfall archive for all stations in the United Kingdom. The majority of rainfall stations in the United Kingdom are now operated by the Regional Water Authorities in England and Wales and by their equivalents in Scotland and Northern Ireland. It is a measure of the interest of the general public in the weather that a substantial number of rainfall stations are still run by private individuals who either co-operate voluntarily with the Meteorological Office directly, or via a water authority.

The Meteorological Office and water authorities each operate and control limited, independent rainfall-observing networks that report for their respective,

more immediate, operational purposes. However, besides these operational rain-gauge networks the much more extensive networks of daily and monthly read gauges provide information for climatological purposes, usually some time after the rainfall has occurred. The application of these data to planning and design problems may be less frequent and the need for them less apparent. Nevertheless, the prime beneficiaries of a sound data base over a given region include those concerned with the water resources of the region, their extent, their variability in space and time and their control and exploitation. The Meteorological Office takes a long-term view and continues to archive all rainfall observations received that are made in a scientifically acceptable way. The extensive collaboration with water undertakings throughout the United Kingdom in the collection of rainfall data involves a healthy two-way exchange of information; mutual help is given in the large effort needed to maintain and check adequate observing practices. However, there are pressures on water authorities to cut costs and this has been reflected in moves to reduce the rainfall station network. Costs of data collection are not high (as rainfall measurement is rarely time consuming) though the extra charges involved in data quality control and archiving may exceed those for network maintainance and operation. The Meteorological Office accepts the need for some network rationalization. This has resulted in studies with the Institute of Hydrology, under the sponsorship of the Department of the Environment, of methods that could be applied to arrive at acceptable rain-gauge spacings. The distribution of rain-gauges should be compatible with user needs for appropriate levels of accuracy in rainfall estimates both at points between gauges and over areas of different size. This year a study commenced with the full co-operation of the North West Water Authority of the requirements for rain-gauging over its area in which a new quantitative weather radar will be operating in 1980. The earlier work and issues involved in rationalization were aired at a meeting of engineers and hydrologists with a broad spectrum of interests.

The computer-based index of rainfall stations in the United Kingdom, known as RAINMASTER, continued to expand during the year. Further historic stations were listed where information became available in sufficient detail. The mixture of computer-based and manual-based procedures for the quality control of rainfall observations continued to develop. These procedures are necessary to attempt to correct a minority (typically about 5 per cent of the total) of suspect or incomplete observations. Details of the procedures used have been discussed in previous *Reports*. Modifications to the procedures have been necessary to streamline the manual procedures for quality control and to deal with the widespread and unusually heavy snowfalls of the two recent winters. Snowfall places particularly large demands on quality-control skill, as a considerably greater proportion than usual of observations are either suspect or missing. It has been found that the use of computer-drawn maps produced under the control of the human analyst contributes significantly to a satisfactory assessment of both widespread heavy snowfall and heavy rainfall events.

The precision encoding and pattern recognition (PEPR) equipment of the Nuclear Physics Laboratory at Oxford continued to be used to extract detailed rainfall information from daily autographic charts. About 750 000 such charts have now been processed, 350 000 of these from a network maintained by the Greater London Council. A little of this extensive information has already been used in investigational work concerned with storm-drainage design.

In many remote areas, and in other situations where frequent manual attention is difficult, fully automatic rainfall recorders are needed which can be left for a month or more with little attention. About 80 automatic magnetic-tape rainfall event recorders (MTER) are now deployed under the control of the Meteorological Office or with its direct participation. The majority are installed in Scotland and northern England, whilst the number in a special network over catchments of the Severn–Trent Water Authority near Gloucester was increased to replace some older, chart-based recorders that required daily manual attention. Several other MTER are currently placed in the Cotswold hills adjacent to this network.

Some rainfall observations were published in the *Daily* and *Monthly Weather Reports*. The old annual publication *British Rainfall*, the last volume of which covered the year 1968, has been replaced in part by a new publication entitled *Monthly and annual totals of rainfall for the United Kingdom*. Volumes of data for 1969 and 1970 were published in 1979.

The number of hydrometeorological enquiries in 1979 was at a similar level to that for the previous two years, though the number of more complex enquiries markedly increased, with a partly compensating fall in telephone enquiries. As in previous years, most were related to building, drainage and legal matters, but there were enquiries of all kinds concerned with very recent rainfall. The importance of rainfall information to the construction industry is shown by the introduction, after consultation with the Meteorological Office, of a special application form for rainfall data by the National Federation of Building Trade Employers. Few building sites are more than a few kilometres from a rain-gauge, so that useful data can be supplied for most places and occasions. The basic information required to answer these enquiries is held readily accessible in the computer, and recent data (for the past 2 or 3 years) can be presented on a display screen immediately. Besides the facility to provide data in formats determined by users of the information, many programs exist to answer more extensive enquiries requiring processed information. For example, much use continued to be made by engineers (particularly those concerned with the design of urban drainage systems) of a suite of computer programs which enable tabulation to be made of rainfall totals or intensities for specified duration (from 1 minute to 25 days) which may be equalled or exceeded in a wide range of return periods. The return periods range from as often as twice a year to as seldom as once in 1000 years and the information can be provided for any National Grid Reference in the British Isles, no matter whether a rainfall station exists there or not. In addition, distributions of rainfall within storms for design purposes can be specified.

In this context special mention is made this year of the involvement of a staff member in the work of the Department of the Environment/National Water Council (DOE/NWC) Working Party on the Hydraulic Design of Storm Sewers whose deliberations are drawing to a close. The Meteorological Office has played a full part in the development and presentation of a suite of new urban drainage models which are undergoing final testing. Membership of the committee has clearly resulted in the existing Meteorological Office services for drainage becoming more generally known.

Much time continued to be spent on work for the Water Data Unit (WDU) of the Department of the Environment, including the commencement of the derivation of average monthly rainfall for 1941–70 for the 900 catchment areas

that form part of the *Surface Water Survey* monitored by the Unit. Estimates were made (almost entirely by computer, using digitized catchment boundaries) of annual average rainfall calculated at 3⅓ km spacings, together with monthly rainfall maps based on calculated rainfall at 5 km spacings. A large amount of material was supplied for the publication *Water Data 1978;* this included maps of annual rainfall and potential evaporation for 1978 (in millimetres and as a percentage of average) and a map of hydrologically effective rainfall (rainfall contributing to permanent ground water and run-off). Major work on catchment studies for the Central Water Planning Unit, work which had been going on since 1978, was finally completed with the estimation of daily rainfall over lengthy periods for the remaining two catchments. In addition, this Unit was supplied with rainfall maps for a number of historical drought periods.

The year 1979 saw a significant involvement by the Office in a field project run by the Scottish Development Department (SDD) and the (Scottish) Central Regional Council. Rainfall data from an on-site Meteorological Office magnetic-tape event recorder were processed and presented for use in computer models being used by the SDD; the study is concerned with water quality problems associated with overflow from a combined storm sewerage at Bannockburn.

Much of the work in the hydrometeorological enquiries section is concerned with estimation of components of the water balance—rainfall, potential evaporation, actual evaporation, soil moisture deficit and hydrologically effective rainfall. A versatile program exists which permits calculation and tabulation of these components, for daily or monthly periods for a point or area, and the resulting data can be entered on magnetic tape. One large enquiry dealt with by the use of this program originated from the Institute of Hydrology. Daily rainfall, potential and actual evaporation, soil moisture deficit and hydrologically effective rainfall were calculated for the Thames at Eynsham for the years 1882 to 1976. This is one of the few locations for which such extensive catchment data can be produced. Much work was done for the Anglian Water Authority. Examples include estimation of daily rainfall, evaporation, soil moisture deficit and hydrologically effective rainfall for seven catchments for the period 1930–77 and monthly rainfall for 27 catchment areas and six ground-water units from 1961 to 1978. Further work was completed for the Severn–Trent Water Authority on estimation of rainfall, evaporation and hydrologically effective rainfall for eight Shropshire ground-water extraction units. Information on average annual rainfall and potential evaporation was supplied to the North West Water Authority for 14 catchment areas in west Cumbria, notably in the Derwent basin, in connection with the proposed augmentation of water supplies in the area. Information was also supplied to firms of consulting engineers in connection with this proposal; this included estimates of monthly rainfall in the period 1951 to 1978 over the Wastwater, Ehen and Calder catchments and calculations of the volume of rain-water falling on Wastwater within various time intervals and having a 100-year return period.

The number of requests by water authorities and research departments of universities for the supply of hydrological information on magnetic tape rather than, for example, in the form of printed tabulations, continued to grow. Manuscript data transferred to computer media by outside users were in turn supplied to the Office and are a useful way of enhancing our bank of machinable rainfall data.

The Branch has carried out considerable research into snow problems in recent years. Among the enquiries dealt with this year was one for a firm in the USA in which estimates of return periods were calculated for snow depth, number of days with snow, number of hours of moderate or heavy snow and mean rate of snowfall at Bude, Cornwall. Maps of the equivalent water content of snow over the United Kingdom were constructed for events on several days in the severe wintry weather at the beginning of the year, and the resulting information was disseminated through the weekly Hydrometeorological Bulletins (MORECS) and the Weather Centres. Studies were also carried out into the snowy winters of 1977–78 and 1978–79.

MORECS (Meteorological Office Rainfall and Evaporation Calculating System), inaugurated in early 1978, became well established as a routine weekly service and was well received. The system allows for calculation of evaporation; it also includes further developments of the Penman evaporation equation, suitable allowances for aerodynamic and stomatal resistances, an allowance for the transfer of heat in and out of the soil and improved estimates of long-wave radiation. The service provides, for 40×40 km squares, maps showing weekly and monthly total of 14 hydrometeorological variables including potential and actual evaporation, potential and actual soil moisture deficit, and effective precipitation for grass and for real land use appropriate to each square. Also available are total precipitation and average sunshine, temperature, vapour pressure and wind speed over the same periods of time. Seasonal changes of land use and crop cover are taken into account as is the leaf cycle of deciduous trees. Soil moisture deficit is tabulated for different crops for each square. Output is available in several options. Developments to the system during the year have been aimed at replacing the rather coarse estimates of rainfall and evaporation over 40×40 km squares by the finer definition which 20×20 km squares produce. With the co-operation of regional water authorities a successful trial for acquiring additional meteorological input for the system was carried out. A particular need exists for further daily rainfall totals at weekly intervals. Other improvements included reductions in the rather unrealistically large estimates of evaporation near coasts. A description of the system was presented to the recent meeting of the European Geophysical Society in Vienna and a more comprehensive account was submitted for inclusion in the *Casebook on operational assessment of areal evaporation* to be published by the World Meteorological Organization. A complete account of the system is to be published by the Meteorological Office as a *Hydrological Memorandum.*

The Meteorological Office co-operated with the Institute of Hydrology in a project to compare MORECS estimates of soil moisture deficit with those obtained from neutron-scattering soil moisture measuring instruments. Arrangements were made for presentation of MORECS and other hydrometeorological data on Prestel.

Enquiries relating to overseas hydrometeorological conditions continued to expand and the Branch is building up an archive of data and literature to deal with such work more expeditiously. Principal matters of concern are usually rainfall depth–duration–return period analyses of the type familiar from Flood Studies work in the United Kingdom, probable maximum precipitation studies (mainly for dam design) and components of the water balance for catchments. Many enquiries in the first category were dealt with this year, for North Africa and Arabia (especially the Gulf States), for Canton and the Ivory Coast, while an

enquiry for Dar es Salaam, Tanzania, has included the many aspects of climatology besides hydrometeorology involved in the comprehensive re-design of storm drainage and foul sewerage systems for this city of 750 000 inhabitants. Added impetus has been given to the establishment of an integrated overseas archive by a request from the Military Vehicles Experimental Establishment, Chertsey, for heavy rainfall intensities for durations 5 to 120 minutes and a return period of 10 years, for 200 locations scattered over much of the globe.

Turning now to projects of a longer-term nature, further progress was made in the lengthy task of assembling, from various sources, an archive of monthly averages of air temperatures, duration of bright sunshine, vapour pressure and wind speed for a representative selection of sites in Great Britain from the 1880s onwards for use in future hydrological and other studies. A review was initiated of the climatology of heavy rainfall in the United Kingdom prepared several years ago (and published in Volume II of the *Flood Studies Report* for use in hydrological design). This work is being carried out partly to expand and comment on a number of points made in the last few years at scientific meetings.

The measurement of rainfall by radar has now started in parts of western England and Wales. Although these measurements are primarily intended to improve substantially short-period weather forecasts, they have many implications for rain-gauge networks, rainfall quality-control procedures, and rainfall archiving systems for enquiries and research. A particular area of concern involves the existence and desirable integration of two simultaneous views of the rainfall field provided by radar and rain-gauges. Studies aim to combine these to provide a single 'best estimate' rainfall archive. It is clear that the work will have to proceed in carefully phased stages as the scientific problems are considerable; at the same time the benefits of developing services that incorporate and present these data as soon as practicable, especially for enquiries concerning recent rainfall, may also be considerable.

Co-operation of hydrological matters continued at international and national levels through such bodies as the World Meteorological Organization, the UK National Committee for International Hydrology, the Royal Society sub-committee on Hydrology and the Institution of Civil Engineers Hydrological Group. The Meteorological Office contributed to proposals that led to the establishment of a UK National Centre for the WMO Hydrological Operational Multi-purpose Sub-program, which seeks to give information to developing countries about available hydrological technology.

Services for Agriculture

Direct support for agriculture continues to be provided chiefly through small outstation teams of meteorologists who work in collaboration with members of the agricultural advisory services, with suitable assistance from a headquarters unit. Thus in England and Wales units attached to regional centres of the Agricultural Development and Advisory Service (ADAS) at Bristol, Cambridge, Reading and Leeds provide advice to ADAS specialists on the very wide range of agricultural activities which are sensitive to weather. In Scotland the agricultural extension service is the responsibility of the Department of Agriculture and Fisheries for Scotland and is organized through the three Scottish Colleges of Agriculture, with meteorological advice to the college

specialists being provided by the staff of a unit based at Edinburgh.

The largest group of agricultural meteorologists is located at Bracknell. Here the easy access to the Office's computer data banks allows the rapid processing of a variety of data which are required by both the outstations and the Bracknell unit, as well as by various sections of the agricultural industry and by research institutes. Routine issues include daily messages on the likelihood of the development of a number of plant diseases which are sensitive to weather, compiled from the synoptic data bank; these messages are sent to plant pathologists of the advisory services in England, Wales and Scotland.

Many of the enquiries dealt with were straightforward and were answered fairly readily by use of the data banks or by clear-cut applications of the principles of environmental physics. Our ability to answer with confidence some of the more difficult enquiries stems from the knowledge accumulated as a result of the large number of special investigations carried out over the past three decades, and recorded in nearly 900 internal reports and in numerous papers in the scientific literature. Once again a substantial part of the Branch's activities has been concerned with work on a variety of these special investigations. Many of the studies have been carried through with substantial assistance from, or in collaboration with, other organizations. Agricultural meteorology is an area where such collaboration can be particularly fruitful because so many of the problems which are tackled require a basis of knowledge which is far broader than a meteorologist on the one side or an agricultural scientist on the other is likely to possess. Additionally the meteorologist often plays a further important role because his formal skills and training are well suited to the *quantification* of many of the agricultural processes which he studies.

Grass, whether grazed or conserved as hay or silage, is one of our most important crops and it is appropriate therefore that studies have continued on several aspects of this crop. They have included consideration of the timing of the application of nitrogen fertilizers early in spring, the relation between soil moisture deficits in late spring and mid-season yield, and the detailed modelling of the micrometeorology of hay-drying. The results of experimental 3-day forecasts of rainfall probability and atmospheric 'drying power' made at a number of forecasting offices in 1978 were analysed to assess their use in hay- and silage-making, but it is clear from the outcome that further advances need to be made in forecasting rainfall amount before such schemes can become operational.

The growth and yield of most crops are strongly dependent on the availability of water to the plant roots which in turn is affected by the imbalance between evaporation and rainfall. Many crops respond profitably to irrigation in most years and a considerable amount of work has been carried out or is under way on aspects of irrigation, evaporation, and the water balance beneath crops. Short-term irrigation need is calculated on a routine basis but longer-term planning to assess maximum equipment and water-storage requirements is at present based on an atlas of irrigation need produced a number of years ago. A more flexible planning scheme is now being developed which will allow the likely irrigation water needs in dry years to be assessed by computer calculation using more accurate evaporation formulae. The calculation uses special climatological data sets, and allows the assessment of more complicated irrigation schemes than hitherto. The meteorological sections of a new edition of the Ministry of Agriculture, Fisheries and Food (MAFF) *Technical Bulletin* on irrigation have

been revised to take into account the new work. Studies have continued on improving the algorithms used to estimate evaporation on a routine basis. The way plants respond to soil moisture deficit is an important factor in the calculation of evaporation and here a substantial study of the response of cereal crops to soil moisture, carried out in conjunction with the Scottish Institute of Agricultural Engineering, has been completed. At the request of the Institute of Hydrology a comparison is being made of the variation of soil moisture at a number of sites as measured by neutron probes over several years and corresponding estimates obtained by using the Meteorological Office Rainfall and Evaporation Calculating System (MORECS). An assessment will then be made of whether in the future the MORECS results can replace satisfactorily the accurate but expensive probe measurements. A large number of calculations are again being made of excess winter rain and duration of field capacity at a number of sites where the third and final year of comprehensive drainage experiments by the Field Drainage Experimental Unit has concluded. A theoretical study was initiated on the heat flux in the soil beneath crops and of soil temperature in relation to standard meteorological measurements such as screen temperature. It is hoped that the results will lead to the more accurate estimation of available energy for use in the calculation of evaporation; they will also find application in studies of the early stages of growth of newly sown crops.

Agriculture is a considerable user of energy and with recent shortages of fuel and increased prices there is now much interest in fuel saving in the industry. Assistance has been given on a number of MAFF projects involving the use of natural or artificial shelter-belts to reduce heat losses from glasshouses and lessen the risk of damage in strong winds. A theoretical study was made of a solar water-heating system in a dairy which has led to the design of improved equipment which will be installed at a College of Agriculture.

The relations between yields of crops and weather have continued to receive much attention. Photosynthesis models of the yield of maize and barley have been constructed. Regression models of the yields of grass, sugar-beet and tomatoes were developed, and similar techniques are now being used to relate cereal yields on a regional basis to variables such as temperature and soil moisture deficit.

Plant diseases and insect pests cause a significant loss of crop output each year and interest has been maintained in the study of the relationships between disease and pest development and weather. Tests of a detailed computer model of potato blight using hourly weather observations have produced good results and an operational version of the model is now being constructed. A method for predicting the hatch date of pea-moth eggs was developed in conjunction with ADAS entomologists, and when combined with the 3-day forecasts issued by the Central Forecasting Office at Bracknell it has proved valuable in the timing of sprays against this pest. A study of the aphid infestations which were widespread during the summer demonstrated that these were native in origin rather than a continental invasion. Work continued in conjunction with the Operational Instrumentation Branch on the building of an automatic crop-environment monitor which calculates automatically from its measurements severity indices for the development of five difficult plant diseases. Most pests and diseases are controlled by crop-spraying and further studies were made of the number of days available for various spraying operations, and how these are being changed by the introduction of new spraying techniques.

Advice on climatic aspects of the potential of land for crop production was provided through membership of a MAFF working party on land-use classification. A major study in which the climatic averages of agriculturally homogeneous areas in Scotland have been calculated has been completed. Work on mapping the areas in Britain suitable for production of grain and forage maize was also completed, as was a joint study with the National Vegetable Research Station of areas where outdoor tomatoes may be grown with a satisfactory commercial return.

Yearly livestock losses, either through adverse weather conditions or through diseases which respond in some way to weather, are very large and a significant effort has again been devoted to studies of weather in relation to animal production. Foot-and-mouth disease remains a significant threat to pigs and cattle even though stringent import controls and other measures have prevented any outbreak in Britain for ten years. The virus can be spread by the wind and meteorologists are organized to join at very short notice a MAFF epidemiology team which would be deployed in any future outbreak. Meteorological procedures to be followed in the event of an outbreak were reviewed and tested during the year. Meteorological analyses of previous outbreaks in Northumberland and Malta were made in collaboration with the Animal Virus Research Institute. A joint study with Reading University and MAFF of lambing losses in a lowland flock was continued this year and the meteorological conditions in which small lambs are at risk have been defined fairly closely in relation to heat losses from the animals. Assistance is now being given to the Central Veterinary Laboratory in the environmental monitoring of pig houses in an investigation of high autumn levels of abortion. Further work was done on modelling the development and survival of larvae which cause parasitic gastro-enteritis in animals.

A joint display prepared and manned by staff from the Agriculture Section, the Public Services Branch and the Radar Research Laboratory at the Royal Agricultural Show attracted thousands of visitors. A display at the Horticulture Exhibition earlier this year at Brighton manned jointly with staff from London and Southampton Weather Centres was also very successful. An exhibit was also manned at the Dairy Event in September but evoked a much smaller reaction.

A considerable number of talks and lectures were given during the year to a variety of groups and organizations. A two-day course for ADAS staff on agricultural meteorology was organized at the Meteorological Office College.

The number of enquiries processed by the outstations increased only slightly this year but demands on Headquarters became substantially greater, with enquiries about 40 per cent higher than in 1978.

Observational Requirements and Practices

This Branch, of which the Marine Division under the Marine Superintendent is a part, has overall responsibility for arranging that regular meteorological observations of suitable quality are made on land, at sea and in the upper atmosphere in sufficient numbers and with an appropriate distribution in time and space to meet national and international requirements. It specifies how meteorological sensors and observing systems shall be exposed, details the observing techniques to be employed and arranges for World Meteorological Organization (WMO) codes to be implemented at United Kingdom stations. It arranges for observing

stations to be inspected regularly to ensure that approved standards of site, instrumentation and observational procedures are maintained. The Branch establishes, on behalf of the forecasting, climatological and hydrometeorological branches, requirements for new or improved sensors, observational systems or practices, and organizes field trials to determine their suitability for operational work, optimum procedures for their routine use and the effect of their introduction on the accuracy and comparability of the basic observational data. It works closely with the Operational Instrumentation Branch on the specification of new sensors or observational systems and on the design of trials to establish the performance of prototypes.

The Branch provides the Chairman and Secretary of an internal working group concerned with reviewing the UK Observational Networks. The working group has produced important policy statements on networks of synoptic climatological and automatic weather stations and is currently preparing similar statements on marine and rain-gauge networks. In the international field the Assistant Director (Observational Requirements and Practices) serves on the WMO Working Group on the Global Observing System (GOS) and attended an Informal Planning Meeting convened by the WMO Commission for Basic Systems to prepare a plan for a study of an improved World Weather Watch system. Senior Branch members serve on international Working Groups concerned with radiation measurements and with the compatibility of data obtained from different upper-air measurement systems as well as on the Advisory Working Group of the WMO Commission for Instruments and Methods of Observation.

Observatories

The Observatories at Kew and Lerwick and the Meteorological Office section at Eskdalemuir (a NERC Geomagnetic and Seismological Observatory) continue to make a wide range of observations of the highest quality. The three Observatories also provide valuable facilities for the impartial testing of new or improved instruments and observing techniques. The program of work at Lerwick is the most extensive of all. In addition to the normal observatory work entailing observations of solar radiation and atmospheric potential gradient, the station is part of the upper-air and thunderstorm location network. Observations are also made of ozone, and Lerwick continues to be a WMO 'base line' station for atmospheric pollution studies.

Surface observations

Several different kinds of surface observations are made to meet particular requirements. For weather analysis and forecasting purposes a network is maintained consisting of observing stations making weather reports at fixed times agreed internationally. It is essential that such reports, known as 'synoptic' reports, should be received without delay. At the end of 1979 the United Kingdom synoptic reporting network consisted of 263 stations, of which 82 made hourly reports and 50 made 3-hourly reports throughout each day of the year. The remaining 131 stations reported less frequently, some closing at night or at weekends. Meteorological Office staff manned 84 synoptic reporting stations, most of which were located at civil and military airfields. At the remaining 179 stations, known as auxiliary reporting stations, reports were made by people such as coastguards, lighthouse keepers and private individuals. Special courses for training auxiliary observers in the making and reporting of weather

observations were held at the Meteorological Office College. When it was not possible for an auxiliary observer to attend one of these courses a member of the staff of a nearby meteorological office visited the auxiliary reporting station and gave instruction on the spot. A number of new-entrant coastguards were given instruction at their Training School at Brixham by an instructor from the College.

There is also a requirement for records of meteorological variables to be maintained over long periods at sites representative of the various types of terrain and urban environment. These 'climatological data' provide information for the long-term averages, extreme values and frequency distribution of meteorological variables and are used in a variety of planning activities, notably in agriculture, town planning and industry. It is important that the exposure of climatological stations should remain substantially unchanged for long periods and this is becoming increasingly difficult to ensure owing to building and other developments near many stations.

Many stations making synoptic reports also submit climatological returns, usually for several observing hours each day. At a number of key climatological stations manned by Meteorological Office staff these returns cover the whole 24-hour period. About 500 other stations make climatological returns only, usually of data read at 09 GMT though some make returns for additional hours. Most of these stations are operated by local authorities or similar organizations but a number are still operated by private individuals on a voluntary basis. Courses for climatological observers were held at the Meteorological Office College and the Edinburgh office. Inspections of both synoptic and climatological stations were carried out regularly, those for climatological stations now being made biennially.

For rainfall a more extensive network is required to provide the data needed to determine the distribution. This information is of great value for water use, control and planning. Data are received from about 6500 stations most of which measure rainfall only, 70 having magnetic-tape event recorders. The majority of rainfall stations are maintained by co-operating authorities, usually Regional Water Authorities, the remainder being operated by a variety of other authorities and by private individuals. The Meteorological Office collects data from rain-gauges that meet suitable standards of exposure and equipment and carries out an inspection program to ensure that these particular standards are maintained. In previous years the rate of inspection of rainfall stations had fallen well below that which is desirable but an increase in inspecting staff enabled visits to stations to be made more frequently. The time interval between inspections at most stations was reduced to about 3 years.

In order to assist the forecasting of weather conditions along major roads a network of 65 stations provide plain-language reports of current weather. These are located at road maintenance depots alongside motorways and at Automobile Association and Royal Automobile Club offices. Reports are made at approximately 3-hourly intervals during daylight hours throughout the year and also during the night in winter months. These stations are inspected regularly.

Automatic weather stations are now sufficiently reliable and accurate to be used to supplement the surface observing system. They cannot yet give the wide range of observations provided by the human observer but they provide the only means of gathering synoptic data from areas, or at times, where it is difficult or unduly expensive to support human observers. Four automatic weather stations

were installed and brought into operation bringing the total in operation up to 9 and plans were made to install 24 others to respond to the initial phase of the proposal of the Working Group on UK Observational Networks.

Observations are required to support the specialized forecasting service given to the offshore industry. An automatic weather station was maintained at Muckle Holm, an island on the approach to the oil terminal at Sullom Voe in the Shetlands, and a new auxiliary station was established to help with forecasting weather for the operation of large tankers in the Sullom Voe. Automatic weather stations were also installed and maintained on oil platforms in the North Sea, on buoys in the south-west approaches and Lyme Bay, and on the Whitaker Beacon in the Thames Estuary. Advice was given to the offshore gas and oil industries on meteorological instrumentation and observational procedures. One officer was based at Aberdeen and dealt with installations within the United Kingdom offshore area north of latitude 55°N. A second officer was based at Bracknell and dealt with installations south of latitude 55°N. A major effort was directed towards obtaining regular good-quality observations from the fixed production platforms for both synoptic and climatological purposes, although advice was also given to observers on the more transitory drilling rigs. Both officers worked closely with the London Weather Centre and represented the Branch at the Offshore Europe '79 Exhibition in Aberdeen.

Radiation observations

There is a long history of solar and terrestrial surface radiation measurements in the Office, notably at Kew Observatory, but it was not until the 1950s that systematic observations were made at a number of stations. At the end of 1979 the United Kingdom official network consisted of 8 stations. Problems with new data-logging equipment (MODLE 3) continued to impede progress on commencing radiation measurements at 6 radiosonde stations, but a MODLE 3 was installed at Crawley on trial so that this station could be brought into the radiation network at the beginning of 1980. At the end of 1979 there were 25 co-operating radiation stations operated by authorities having a hydrological or agricultural interest. These provide data, mainly in the form of daily totals, for which the Office operates quality-control procedures. Regular liaison visits were made to these stations and the Office offers an instrument calibration and repair service with the object of securing homogeneous data throughout the network.

Studies continue of methods of deducing the radiation climate at locations at which observations are not made. The analysis phase of an experiment to test the predictions arising from these studies, involving a dense array of 10 autographic radiation stations, was started. The preparation of a publication of radiation data for the UK 1951–75 was completed and sent for editing.

Reliable radiation measurements of suitable accuracy can only be achieved by daily attention to instruments, by frequent calibration of recording equipment and comparison of instruments against secondary standards. The secondary standards continued to be compared regularly with the national standard Ångström pyrheliometer and the Office's cavity radiometer.

National and international interest in aspects of obtaining energy from solar radiation continued and the Branch was active in the WMO Regional Association VI Working Group on Solar Radiation, the European Economic

Community Solar Radiation Data Acquisition Group and in an International Energy Agency Solar Energy Program group.

Many enquiries from universities and industry were answered.

Runway visual range

Most major airports in the United Kingdom use the observer runway visual range (RVR) system. A count is made of the number of designated RVR reference lights visible to an observer from a known fixed position near the touch-down area. The number is converted by Air Traffic Control staff, using a calibration table, to give the 'visual range' a pilot would see with respect to the runway lighting at the touch-down area.

The normal program of visits to airfields in order to inspect and calibrate RVR installations was carried out throughout the year. This service was provided for local authorities, the Civil Aviation Authority and the Royal Air Force.

Visits were made at six-monthly intervals to 31 civil airports and to 34 Royal Air Force stations in the United Kingdom and overseas.

Upper-air observations

The normal program of upper-air observations comprises pressure, temperature and humidity soundings by radiosonde at 00 and 12 GMT and upper-wind measurements by radar at 00, 06, 12 and 18 GMT. This program was maintained by eight stations in the United Kingdom and at Gibraltar.

This has been a year of consolidation with the new radiosonde (Mk 3) system, as outstation staff became more proficient, and as problems inherent in the new equipment were first identified and then solved. Overall performance came up to the high standard expected, but some difficulties, notably that of interference on the allocated radio frequency remain. The well-established Grawsonde was brought into use at Gibraltar in February with satisfactory results.

The two Weather Ships—the *Admiral FitzRoy* and the *Admiral Beaufort*—were deployed alternately at North Atlantic Ocean Station 'L' (57°N, 20°W). The upper-air program in the ships was maintained at four complete (temperature, humidity and wind) soundings per day.

The performance of high-altitude balloons showed a general deterioration. Fortunately this trend was reversed in respect of regular balloons. The performance of neoprene balloons remains significantly better than that of balloons made of natural rubber.

Thunderstorm location and surveillance

A full program of half-hourly observations by day and hourly observations by night was maintained throughout the year by the network of direction-finding stations. With Malta closing at the end of 1978 this became Gibraltar, Lerwick, Camborne, Hemsby and Shanwell. The operational accuracy of this latter station was threatened by the construction of a gas pipeline, and after running in parallel with a new station at Stornoway for some months to establish site corrections, Shanwell too closed at the end of August.

The total number of storms located during the year was again a decrease on that for the previous year. Some of the reduction was undoubtedly due to a decrease in the catchment area, following the loss of Malta.

User trials and quality evaluation

Trial of a device to facilitate the observation of mean wind speed by non-professional meteorologists at auxiliary stations was satisfactorily completed and another begun on the performance and reliability of a proprietary low-starting-speed anemometer and wind-direction system. An experiment was mounted to identify problems in the observation of surface pressure in south-east England. It is hoped that improved knowledge of exposure problems will emerge. Initial work for a trial of a prototype automatic climatological recording station was undertaken. The Operational Instrumentation Branch participated in an analysis of data they had gathered in a trial of techniques for an automatic system to replace the present thunderstorm location network.

A comparative study of alternative sunshine sensors (one of Meteorological Office design and the other Swiss) for automatic data gathering is well advanced.

A continuing evaluation of data quality was undertaken for several automatic devices introduced into operational service. These include several automatic weather stations on land, equipment deployed on a buoy in the south-west approaches and systems fitted to two aircraft of British Airways (see Plate IV), the data from which are gathered via satellite. Special attention was given to the operational performance of the automatic radiosonde (Mk 3) now settled into routine use. Revised computer programs provided by the Operational Instrumentation Branch successfully dealt with several teething troubles. Despite some remaining problems the radiosonde has a performance well ahead of other designs. A report upon the performance during 1977 and 1978 of 588 radiosonde stations in the northern hemisphere was completed for the World Meteorological Organization, using data provided by the computer support section of the Central Forecasting Branch.

Quality evaluation of automatic equipment deployed in data-sparse areas is hampered by lack of independent information. Alternative techniques for dealing with this problem are under investigation. With the help of the Meteorological Office College a study was begun of the usefulness in this task of weather charts analysed by forecasters of many years' experience. The benefit of redundancy in data from automatic weather stations as a means of quality control and to minimize the need for servicing visits is also being examined.

The marine environment poses special problems. With this in mind a study of initial results for two peristaltic metering devices was undertaken to provide information for the design of a full trial aimed at improving the observation of rainfall at weather buoys. Attention also was given to the suitability of a screen designed for marine use.

Marine Division

The continuing depressed state of the shipping and fishing industries has further reduced the size of the British Merchant Navy Fleet. The withdrawal of the older vessels in favour of larger, faster container ships has resulted in fewer ships making observations for the Office but, because the new ships spend more time at sea than their predecessors, the number of observations received has been maintained and even marginally increased. The seven Port Meteorological Officers at London, Liverpool, Southampton, Hull, Newcastle, Cardiff and Glasgow are responsible for recruiting vessels into the Voluntary Observing Fleet

(VOF) and, largely as a result of their efforts, the depletion of the VOF has been minimized despite the recession. During the latter part of the year a small number of ships which had been withdrawn from service were recommissioned and re-entered the VOF. It is to be hoped that this slight upward trend will continue in 1980.

The Port Meteorological Officers are all master mariners with considerable experience in voluntary observing at sea and, therefore, are able to contribute significantly to the maintenance of a high standard of observing in the VOF. It is gratifying to note that this standard has been well maintained especially as meteorological work at sea in British merchant ships has always been carried out on a voluntary basis.

There is a continuing trend to reduce the complements of merchant ships and it is hoped that the policy of fitting distant-reading marine meteorological instruments and the prospect of the deployment of ship-borne automatic weather stations in newly built vessels will alleviate some of the problems caused by crew reductions. Additionally, trials have been conducted on a small number of vessels of the automatic radio transmission of ships' weather messages.

As in previous years, acknowledgement must be made to the many Commonwealth and foreign Port Meteorological Officers for their valuable services and assistance in the replacement of defective instruments and replenishment of stationery in UK Selected Ships on protracted voyages. These Port Meteorological Officers have also greatly assisted us with the withdrawal and return of instruments from British observing ships which have ended their sea-going careers in ports abroad.

The shipmasters, principal observing officers and radio officers who were responsible for submitting the best meteorological logbooks during the year were, as usual, presented with 'Excellent' awards in the form of books. Similar awards were made to masters and officers on the short sea trades for their work in making sea temperature observations and also to a skipper and radio officer who served in a trawler making and transmitting non-instrumental weather observations. In recognition of their valuable voluntary meteorological observational work over many years during their careers at sea, four shipmasters were presented with long-service awards in the form of barographs.

A quarterly journal, the *Marine Observer,* has been published as hitherto and continues to be well received. The journal contains articles on meteorology, oceanography, etc. of interest to mariners, and a large section of each number is devoted to observations of phenomena of a meteorological or general scientific nature extracted from the meteorological logbooks received from the VOF.

The number of marine enquiries, principally from shipping interests, solicitors, universities and industrial firms has continued to increase. The subjects of the enquiries are extremely varied and this year ranged from the weather conditions experienced by the *Queen Elizabeth* whilst carrying troops across the Atlantic in 1942 to those prevailing during the recent tragic Fastnet Yacht Race.

Under the North Atlantic Ocean Station (NAOS) scheme the United Kingdom continued to operate two Ocean Weather Ships on station 'L' situated at 57°00'N, 20°00'W. The ships, *Admiral FitzRoy* and *Admiral Beaufort*, continuously manned the station throughout the year with the exception of a four-day period during May when *Admiral Beaufort* vacated the station to land a meteorologist whose wife had become seriously ill, and a further 12-hour period later in the same month when a sick crew member was evacuated by helicopter.

The weather ships make hourly surface and 6-hourly upper-air observations (for heights reached in upper-air ascents see Table V on page 78). Sea and swell records using the Tucker ship-borne wave recorder and reports of floating pollutants for the Intergovernmental Oceanographic Commission/World Meteorological Organization pilot project on marine pollution monitoring were continued throughout the year. Sea-water temperature and salinity readings to within 100 metres of the sea bed, observations of magnetic variation, collection of rain-water samples for analysis by the International Atomic Energy Agency and collection of sea-water samples on passage to and from station for monitoring radioactive content were undertaken at regular intervals. On behalf of the Institute for Marine Environmental Research a plankton recorder was towed on about half the voyages to and from station during the year.

Operational Instrumentation

The Operational Instrumentation Branch is responsible for meeting the needs of the user branches for meteorological instruments and data acquisition systems. The requirements of the forecasting, climatological and hydrometeorological branches are examined in close co-operation with the Observational Requirements and Practices Branch, and either the most suitable system composed of existing sensors and data acquisition modules is chosen, or an Operational Requirement defining the need for a new development in an area of measurement or system technology is raised.

The Branch then carries out the necessary design, development and/or adaptation of equipment required to meet the application. When prototypes and pre-production equipments have successfully passed their trials, or suitable equipment is already available commercially, manufacturing contracts are placed for a production quantity of equipment. The Branch is then responsible for the technical progressing of the contract, for acceptance testing and calibration of the equipment on delivery, for planning and installation in the field and, finally, for maintaining and servicing all meteorological equipment on the outstations and for making any subsequent modification of the equipment throughout its life.

Whilst much of the work during the past year has been concerned with the procurement of equipment for which the development and trials have been completed, there are two particular areas of design and development which are worthy of special mention. A series of experiments designed to examine the various ways in which synoptic observations can be recovered reliably from merchant ships of the Voluntary Observing Fleet (VOF), particularly during the ships' 'quiet hours', has been completed. Communication trials have been conducted with a view to the introduction of automatic or semi-automatic data acquisition and transmission systems on the ships. Of the systems tested, the high-frequency wireless-telegraphy (HF/WT) and high-frequency radio-teleprinter (HF/RTT) schemes proved inadequate. However, a simple, cheap semi-automatic system using the geostationary satellite (Meteosat) data collection platform (DCP) facility has been highly successful. Trials of a pre-production DCP on a merchant ship, using a 'store-and-forward' terminal for the entry of deck officers' observations, showed a recovery rate of better than 90 per cent even at satellite elevation angles as low as 1° or 2°. The system is easy to install and operate and can be used on any VOF vessel. A more complex, fully

automatic system, using a micro-computer as the data processor, was also tested successfully. It is, however, only suitable for the latest vessels which have modern navigation systems installed, giving continuous output of position, heading and speed over the ground.

A second area of experimental trials this year has been concerned with the development of an automated system for locating lightning flashes using the Arrival Time Difference (ATD) principle. This system uses accurate measurements at three or more locations of the wave-form and time of arrival of the electromagnetic radiations caused by lightning flashes in order to derive the position of thunderstorm activity, and it is hoped that it will eventually replace the existing manual Cathode Ray Direction Finding (CRDF) network. In October 1978, the first three-week trial took place with experimental stations at Beaufort Park, Shanwell, Camborne and Hemsby. The Hemsby station was moved to Gibraltar in time for a second three-week trial in December 1978. These initial trials provided experience for the major exercise in 1979, when four two-week trials were timed to make measurements at periods of different seasonal levels of thunderstorm activity. These trials took place during May, June, July and September 1979. The data are now being analysed to ascertain the potential of the system and early results are encouraging. The lightning-flash locations appear to show considerably less scatter than those from the manned CRDF system, in spite of the limited ATD network used. However, it is not yet clear if the new system has any systematic errors. A decision on whether to go ahead with a fully automatic operational system will be taken during 1980.

For many years there has been a need for a meteorological instrument museum where some of the antique instruments held by the Office could be displayed to the public. A location has now been found at the Bracknell Headquarters, and the Meteorological Office Instrument Museum was opened in October. A selection of old, unique and interesting meteorological instruments will be on permanent display, and it will now be possible to collect and preserve good specimens of obsolete instruments for posterity.

Co-operative projects: international

There was a continuing involvement in relevant projects run within the European Economic Community scheme for co-operation in Science and Technology (COST).

COST Project 72, which deals with the standardization of meteorological instruments and systems within western Europe, made some progress with its plans to find agreed standards for the interfaces and data formats of developing national weather-radar networks. The United Kingdom proposals envisage the possibility of linking the various national schemes thus forming a European weather-radar network. Five countries, including the United Kingdom, have indicated their willingness to participate in a Memorandum of Understanding and several other countries have shown considerable interest. A senior officer of the Branch attended two meetings of the Technical Committee during the year.

COST Project 43 is concerned with the development of meteorological/oceanographic data acquisition systems on buoys, and with a 4-year experimental pilot project leading towards a European network of Ocean Data Acquisition Systems (ODAS). An Agreement was signed in late 1977, and by June 1979 the necessary seven countries had ratified the Agreement thus bringing it into force. A Management Committee was then set up, on which a senior officer of the

Branch serves as Chairman, and three meetings were held during the year. Further meetings of the North Sea/Baltic/Faeroes/Shetland Regional Subgroup were also held and discussions took place leading to tentative proposals for the deployment of operational ODAS at 60°N, 12°W and 53°N, 12°W under the aegis of international co-operation between Norway, Iceland, Ireland and the United Kingdom.

A joint co-operative comparison and trial of a Norwegian buoy and a United Kingdom buoy was carried out during the year, involving the participation of the Norwegian Christian Michelsen Institute, the Directorate of Naval Oceanography and Meteorology (DNOM) and the Meteorological Office. Laboratory trials of the sensors were completed early in the year and the buoys were first deployed at 60°N, 06°W in April 1979. Owing to a number of problems, only nine weeks of data were obtained during the period up to mid-September 1979, when the experiment was terminated when the UK buoy was lost from its moorings. These data are now being assessed and analysed.

Co-operative projects: national

The Meteorological Office policy with regard to future plans for Ocean Data Acquisition Systems in the continental shelf waters off the United Kingdom was the subject of a Study by the internal Working Group on UK Observational Networks during the year. This study is still under consideration, but an interim statement was sent to the Standing Committee on Ocean Data Stations (SCODS) in which two senior officers of the Branch participate.

An automatic weather station, similar to that placed on Muckle Holm in 1978, has been successfully installed and commissioned on the Trinity House Whitaker Beacon in the Thames Estuary off the Essex coast. Data are being relayed back to London Weather Centre. A derivative of this system has also been fitted to the National Maritime Institute (NMI) experimental tower at Christchurch Bay.

The 8 ft diameter toroidal wave-rider buoy (ODAS 1) was deployed in Lyme Bay for part of the year, but has now been brought in for refurbishment. It is expected that it will be redeployed as soon as the weather permits in early spring 1980.

Efforts to install fully automatic, interrogable automatic weather stations (AWS) on three oil/gas platforms in the North Sea continued, but met with limited success. A serious accident to the Mobil Platform, Beryl A, prevented all access to it for many months, and when it again became possible to send staff on to the platform, there were considerable technical difficulties in the installation. However, by the end of the year the system was successfully commissioned and operational. On Occidental's Piper A Platform a complete micro-computer-based AWS was also installed and commissioned, but unserviceability of the complex communications link has prevented valid data from being transmitted automatically. Work continues to complete this system as soon as possible. The third AWS, for the Amoco 49/27A Gas Platform, was built during the year, and will be ready for installation early in 1980. The data from these AWS will be used in support of the forecasting services to members of the United Kingdom Offshore Operators Association (UKOOA) with whom the Office has close contact.

The Branch played a considerable part in the implementation of the North West Weather Radar Project. This project, financed by a consortium including

the Meteorological Office, the North West Water Authority, the Central Water Planning Unit, the Water Research Centre and the Ministry of Agriculture, Fisheries and Food, consists of installing and operating an unmanned weather-radar system at Hameldon Hill in the Pennines. Apart from the installation and commissioning of the Plessey Type 45C radar and the design and manufacture of monitoring equipment, considerable effort was put into the procurement of the equipment and the planning of various aspects of the project, together with the North West Water Authority, Met O RRL (Malvern) and MOD (PE). The system has a computer output transmitted to various centres, including Manchester Airport and Met O RRL, where the output can be displayed on a television screen. The system became operational at the end of the year. As this is a prototype scheme, it is necessary to monitor performance carefully and to implement any essential modifications to either hardware or software. A small joint working party of Meteorological Office and North West Water Authority staff is responsible.

Procurement/production of new instruments/systems

During the year there was considerably increased activity in placing and monitoring contracts for equipment and systems for which design, development and trials were completed in previous years.

Following the successful procurement of 12 data-logging equipments (MODLE 3) for the radiation recording network in 1977, three further equipments have been purchased to complete the network requirements, and spares and additional modules to increase the number of channels that can be logged by each equipment were obtained.

A contract was placed for a further 20 Digital Anemograph Logging Equipments (DALEs) and these were delivered for test and acceptance by the end of 1979. Forty of these instruments have now been purchased out of a total requirement for over 120. These equipments record wind data on magnetic-tape cartridges, and enable the Climatological Services Branch to process the data rapidly by computer instead of using manual methods.

Sufficient modules have been delivered to make 19 Mk 5B wind-measuring and display systems. These systems, fully designed and developed in the Beaufort Park laboratories, allow data from an anemometer and wind vane to be transmitted over long distances by telephone line, and to be displayed on a variety of different dials and recorders. The installation of these systems at major airfields and selected sites is planned to commence early in 1980.

Following the successful trial of a portable Anemometer Test Set, designed and developed in-house, a further six equipments were procured from industry after an open-tender exercise. These Test Sets are used by the Meteorological Office Maintenance Organization during the routine servicing of anemometers throughout the country.

Two major open-tender exercises were also conducted, involving the technical assessment of bids from several manufacturers from western European nations as well as from the United Kingdom. Following the policy decision that a number of Synoptic Automatic Weather Stations (SAWS) will be required during the 1980s a detailed Requirement Specification was prepared, based on the more general development work on AWS conducted in the laboratories. After a competitive tender, during which there was technical liaison with a number of firms, a contract was placed for 20 SAWS, 10 associated Polling Units (which

will call for the data from the main Meteorological Collecting Centres), spares and documentation. First equipments are planned for delivery in early 1981. A further 30 SAWS will be required in the mid-1980s.

Tenders were also sought from a small number of European firms for the supply of 20 laser-based cloud-base recorders (LCBRs), and a contract has now been placed. This is the first batch of a total requirement for over a hundred LCBRs to be supplied during the 1980s to replace the existing nodding-beam ceilometers which are reaching the end of their useful lives.

Design and development of new instruments/systems

Sensors. This year has seen a growth in the activity directed towards finding suitable reliable sensors for use in automatic weather stations and on standard observing stations.

A major study of the comparative performance and principles of operation of a number of commercially available visibility sensors has been completed and a comprehensive report has been written. It is hoped that this work will provide a firm basis on which to base decisions concerning the types of visibility sensor that can be used with the new generation of synoptic automatic weather stations.

Encouraging progress has been made with humidity devices and with quantitative rainfall measurement instruments. For humidity a technique has been developed for the protection of commercial humidity sensors from the effects of atmospheric pollution, especially from attack by halide salts which can destroy such sensors rapidly. The method involves the deposition of an acetate membrane only a few microns thick directly on to the sensor. This produces a robust form of protection which has little effect on the performance of the sensor. It is now undergoing extensive field trials. A successful field calibration device for use with the PCRC humidity sensor has also been developed and tested. It is based upon the calculable, repeatable relative humidity that is generated above saturated solutions of certain different soluble salts, and is capable of giving a number of calibration readings across the sensor's working range. These developments have gone a long way towards solving the problems associated with providing reliable humidity measurements from automatic weather stations.

Work progressed on a device which will measure both the rate at which rain is falling, and also the total amount of rain that has fallen in a given period. The instrument is based on a combination of the tipping-bucket and weighing principles. Field trials of a prototype have been encouraging, but further work will be required to produce a reliable operational instrument. Further trials on the laboratory-designed, absolute, gravimetric rain-gauge have been conducted, and some further improvements have been incorporated. The three gravimetric rain-gauges built were deployed at the end of the year in the experimental site at Beaufort Park, and a further comparative trial is under way.

A variety of smaller developments have been pursued, including devices to monitor the wetness of natural surfaces (important in certain crop disease problems), a special type of exposure screen for use on high masts and towers and an improved system for measuring the soil temperature profile.

Automatic weather stations. Further progress has been made towards the completion of the four Continuous Automatic Remote Display (CARD) systems at RAF and Army ranges. Systems have been installed and commissioned at

Theddlethorpe (Donna Nook), Wainfleet and Sennybridge (Tirabad), but all have suffered from interruptions due to problems caused by the mains electricity supplies and from technical difficulties. Site works are in hand for a fourth system at Otterburn, and the hardware has been prepared.

A prototype automatic climatological recording equipment (ACRE) has completed its hardware and software engineering tests and has been handed over to the Observational Requirements and Practices Branch for an extensive field trial. Work has also continued on a small microprocessor-based automatic system for monitoring the conditions conducive to the development of certain crop diseases. The prototype for this instrument, known as a Crop Disease Environment Monitor (CDEM) is expected to be available in spring 1980 for the 1980 disease season.

Radiosondes. During 1979, work on the Mk 3 radiosonde system has continued on a number of fronts. The ground-station software for the routine synoptic stations has been revised and accepted by the Observational Requirements and Practices Branch, and the new issue was passed to the outstations in August 1979. The most obvious change is an improved method of selection of significant (message) levels at which changes in temperature or wind gradient occur. The previous issue conformed with WMO rules, but the new version corresponds more closely with the choice that would be expected of an experienced meteorologist. Other changes make it easier for the operator to handle the archiving of data reliably and correct some undesirable features of the previous issue.

The Mk 3 radiosonde ground station, in its routine synoptic form, is not completely satisfactory for the four Army range stations which fly sondes for experimental purposes. A contract has been placed to modify four standard stations by the addition of a matrix printer and some extra software. In the modified system, data are taken from the radar at a high rate, and then filtered to reduce radar noise. Partially processed data are output to the printer in real time, so that high vertical resolution measurements can be calculated. It is intended that the data will also be input automatically to a calculator. This will allow further rapid processing to be carried out, such as the prediction of acoustic focusing of explosions or gunfire, which could cause annoyance or damage to local households. The software also allows several sondes to be launched in succession, using previously stored calibration data. This contract is planned to be completed during 1980.

During the approach to sunspot maximum, expected to peak during April 1980, there has been a considerable increase in the interference on the Mk 3 radiosonde telemetry link, currently on 27.5–28.0 MHz. A trial has been started to see whether the use of a directional receiving antenna will significantly decrease the interference level. Some low-priority work has also taken place on the use of digital filtering techniques to analyse the telemetry signal, and so to improve the signal/noise ratio by removing systematic interfering signals. In the longer term, particularly with increasing activity on the American Citizen Band, it will almost certainly be necessary to move the telemetry frequency to the 400 MHz band. Suitable forms of 400 MHz transmitter are being investigated, with a view to finding a sufficiently stable oscillator at as low a cost as possible.

Weather radar. The increase in work concerned with the experimental weather radar network has continued, much of it in collaboration with the Meteorological Office Radar Research Laboratory (Met O RRL) at Malvern. Apart from

the considerable involvement in the North West Radar Project mentioned earlier, there was further work to make the Camborne system fully operational and a system was installed and commissioned at Upavon at the beginning of the year. Data from Camborne were transmitted to Plymouth meteorological office and to the South West Water Authority, who found it valuable even though it is not yet of the highest accuracy. This accuracy will be greatly improved when three sets of calibrating rain-gauges have been installed and the calibration data are transmitted on demand every hour to the on-site computer.

The Branch was involved in the procurement exercise for Radar Display Systems. This equipment takes digital data transmitted from a radar and reproduces it on a television screen. The equipment also has the ability to store and replay nine previous pictures.

The Branch was responsible for setting up a small working party to produce a new Specification for an operational weather radar, to be written in the light of experience gained in the North West Weather Radar Project and the current state of the art. This Specification will be used in the procurement of a new radar which it is hoped to site in the London area within the next two years. Considerable work went into seeking a suitable site; the nature of the terrain and the large and extensive tall buildings make it difficult to find a good radar exposure with little ground clutter.

The proposed London area radar is expected to be supported financially by the Meteorological Office, the GLC and one or more of the neighbouring water authorities. To this end, discussions have taken place with Thames, Southern and Anglian Water Authorities.

Technical management and services

The Branch is responsible for the provision of technical services and facilities to all user branches within the Meteorological Office as well as to its own development sections. These include mechanical and electronic workshops, an engineering drawing office, the technical aspects of procurement, technical documentation, routine test and calibration, installations, maintenance and post-design and photographic services.

Work coming into the Mechanical Workshops at Beaufort Park and London Road has continued at a moderate level, but recruitment difficulties have made it impossible to fill several posts that exist in the craftsman grades, which ended the year with four vacancies in an establishment of ten. Machine tools in the workshops continue to be progressively upgraded when replacements are necessary.

The policy of contracting the bulk of the drawing work out to private firms was continued, and the budget for this outside work was fully utilized in carrying out the program. Substantial items included the design and drawings for the construction and installation of marine and land-based automatic weather stations, and the design and drawings for an automatic apparatus for measuring the cosine response and absolute calibration of radiation instruments. Outside manufacturing firms are now bringing automated numerical control into their production lines, and this has required the redrafting of some of our standard printed-circuit-board drawings to meet the higher standards required by digital techniques. Several contractors have started to use computer-aided design techniques, and drawing office staff have run an evaluation exercise to ensure that these techniques are cost-effective compared to an in-house system.

Engineering drawings are now stored using a microfilm system, and triple sets of aperture cards are held for 30 000 such drawings. Archival storage of the originals has been organized by the Meteorological Office Archives section.

The services of the Senior Photographer have been requested by many branches this year. Visits have included Southampton Weather Centre, Manchester Airport and Glasgow Weather Centre in addition to the coverage of Royal visits and 20 other location appointments. There has been an increasing work-load, and, despite attempts to make use of other departments and commercial studios, a backlog of monochrome print production has developed. A new monorail technical camera was acquired to improve the studio capability.

During the year the Technical Documentation section was busy. Thirty-two specifications and instructions were written or edited and processed for publication. A running contract with a local firm produces a fairly quick response to the need for new or amended handbooks for routine equipment. The rewriting of Part I of the *Handbook of Meteorological Instruments* also made good progress. The first volume (Pressure) was sent for printing, the second and third are being edited for printing, and the fourth to sixth are in various states of preparation.

An increasing range of technical enquiries was received from commercial firms, other government departments and public authorities, as well as from the public. Interest in alternative energy sources and solar houses led to a marked increase in enquiries concerning suitable instrumentation in order to make preliminary investigations.

The Branch maintains a library of Defence Standards for reference by designers. These are of importance, but it should be noted that meteorological instruments, by virtue of their semi-commercial nature, tend to be built to a lower quality than that of military equipment. As a result, costs are usually considerably lower.

During the year a catalogue of the Branch's photographic negatives from 1953 onwards was completed. These are often of great value in responding to queries.

The work of routine test, calibration and acceptance of equipment proceeded as usual. This activity is vital to the well-being of the Office's meteorological observations. Increasing emphasis is being placed upon the periodic recalibration of electronic and electrical test equipment, the accuracy of which is necessary for the work of the Maintenance Organization and in the Office's development and research laboratories. The Mk 3 radiosonde calibration plant at Eastern Road continued to operate satisfactorily and a stock of calibrated sensors has been built up for use by the upper-air stations. Some work has begun aimed at improving the conditions in the working area where at present there is considerable noise and heat.

The number of instruments tested and calibrated is shown in Table XV.

The installation section was very busy during the year, owing to the increase in the delivery of new systems from production contracts, and the need to move several equipments from experimental trial sites to their operational locations. Digital Anemograph Logging Equipments (DALEs) and radiation data logging equipments (MODLE 3) are now being installed operationally. Several Meteorological Office Weather Observing Systems (MOWOS) have been moved; new locations include Leconfield, East Malling, Grantown-on-Spey and Little Rissington.

The Cossor wind-finding radars which had previously been withdrawn from Cyprus, Masirah and Malta are to be used in the United Kingdom. One has been installed and commissioned at the Royal Aircraft Establishment, Aberporth, and another is scheduled for the Meteorological Office Radar Research Laboratory, Malvern, in connection with the Short Period Weather Forecasting Pilot Project. The third has been installed at Cossor Electronics Ltd, Harlow, in connection with a refurbishing scheme. The company is contracted to determine what updating is necessary to ensure the successful operation of their radars for at least a further 10 years. The opportunity will be taken to improve performance.

The installation team has also continued to work on the instrumentation on the Lichfield IBA mast. A marine-type screen has been modified to contain a wet bulb, and the cup-contactor anemometers which proved unreliable in service on the mast last year have been replaced by cup-generator anemometers. Equipment has been obtained to allow the Office to interrogate data being collected on the Belmont mast by the Central Electricity Research Laboratories. This equipment will be moved to Conningsby early in 1980 for a user trial to test the value of the data to forecasters.

The work-loads of the Post Design Services (PDS) and Electronic Workshops have continued at a high level. At any one time PDS have about six major tasks in hand with a further six to eight awaiting attention. Several manufacturing tasks taken on by the Electronic Workshops were delayed owing to a shortage of components. These workshops can now undertake the repair of high-technology printed-circuit boards (pcbs) and devices, and there is a facility for the limited production of prototype pcbs. A separate repair bay has been established within the stores area at Western Road, and the service it provides proved very convenient in repairing some items at short notice to meet emergency requirements.

The Buoy Servicing Shelter was completed by the Property Services Agency (PSA) and handed over on 31 August 1979. Plans have now been made to improve the office accommodation at Beaufort Park; planning permission has been given and the work has been put out to tender by PSA. A major section of the roof of the Branch main building at Beaufort Park was stripped and re-covered by a contractor during the year. Other works services included the repair of the doors and floor of the rotating balloon shed, and a re-location of the solar radiation calibration equipment into more spacious accommodation.

Maintenance and technical training

The Meteorological Office Maintenance Organization (Met O MO) continues to provide the meteorological offices at home and overseas with a comprehensive field support service. The 21 maintenance centres in the United Kingdom now provide technical cover for more than 1150 instruments and systems installed at 330 widely scattered locations. These maintenance centres, placed as close as possible to the centre of their work-loads, are manned by small teams of technicians (typically 2 or 3) who visit meteorological offices and remotely sited instruments at regular intervals to carry out a program of preventative maintenance, inspections and field calibration checks. Visits are also made at short notice in the event of equipment failure, and for the radar systems an 'on-call' facility has been implemented.

A major area of work is concerned with providing technical support for the

HQ Communications Centre. Here maintenance teams provide a full 24-hour cover for the computer-based message switching system AUTOCOM and the facsimile complex. Within the Communications Centre a large number of electro-mechanical devices are in use. Some are peripherals to the computer system, such as storage disc drives, line-printers and teletypes, while others form part of the facsimile 'store and forward' system. Satisfactory throughput of meteorological data is dependent upon the reliable operation of these equipments, and a comprehensive maintenance program is required to ensure that satisfactory performance is attained. The scope of the work continues to increase as new communication equipment is introduced. Met O MO staff are now concerned with the maintenance of MODEM equipment and are co-operating closely with the Telecommunications Branch to monitor and identify equipment/line failures associated with data transmitted on the main trunk circuits feeding AUTOCOM.

The work in the regions continues to grow both in quantity and technical scope. The majority of the Mk 3 Radiosonde Ground Stations are now in service, and the maintenance centre at Beaufort Park is now supporting the Mk 3 radiosonde calibration plant at Eastern Road, Bracknell. New types of data logger and automatic weather stations, some employing microprocessor techniques, are being deployed at land stations and offshore. The offshore systems include instruments located on buoys, remote islands, oil rigs and ships. In many cases the technology used in these systems is new to the field technicians and to ensure the successful introduction of these equipments close support from Headquarters is provided.

An agreement has been reached with MOD(Navy) for Met O MO to undertake the maintenance of facsimile equipment at MOD(Navy) installations; in return they will provide repair facilities for Meteorological Office facsimile (printed-circuit boards) on an exchange basis. This arrangement is proving to be a cost-effective measure for both services.

Technical training continues to be carried out on behalf of the Assistant Director (Professional Training) at the School of Technical Training at Beaufort Park. As the variety and complexity of electronic meteorological instrumentation continues to expand, there is an increasing demand for trained technical staff to support the instruments in the field. The courses contained in the annual program include the new equipment coming into service and also those deployed for some years (see Table XVII). It is also necessary to provide within the syllabus relevant background knowledge of recent technological developments which are being incorporated in the design of new instruments. Considerable emphasis is placed on instruction covering the practical aspects of equipment maintenance. In addition to the routine courses provided for trainee technicians, an induction course is held prior to the basic electronic training they receive at RAF Sealand. This course is aimed at ensuring that the starting level of all students is reasonably uniform. Subjects included in the syllabus are Mathematics, Engineering Science, Electrostatics, Magnetism and Basic Electronic Measurements. Arrangements are also made, when requested, to include students from overseas and MOD(Navy) in the training program.

Overseas teams continue to provide local maintenance facilities. Additionally, visits are made from time to time to stations in Africa and elsewhere in support of the WMO Voluntary Co-operation Program.

Computing and Data Processing

The operation, maintenance and development of the resources of the central computing facility, known as COSMOS, are the responsibility of the Data Processing Branch. One of the most important functions of this Branch continues to be the operation of a suite of programs designed to process observations received in the telecommunication centre and to produce, from these, analyses and forecasts for operational use. Though these operational requirements are allotted the highest priority, a large proportion of computing capacity continues to be devoted to tasks other than analysis and forecasting—in particular research projects requiring long-period integrations.

The COSMOS computing installation

The central computing facility continued to be based on two IBM machines, a 360/195 installed in 1971 linked to a 370/158 dating from 1975. This year enhancements were effected to the backing store of the coupled system. New CDC discs and disc controllers were added, the discs including some with 'fixed-head' design, enabling data to be retrieved more rapidly. The on-line direct access storage is now 4400 megabytes, equivalent to 1.1×10^9 64-bit numbers. These changes have helped to reduce a bottleneck in the flow of data into and out of main storage.

Nevertheless, with the planned use of computing services continuing to increase, the computing facilities have again reached saturation. The increased demand has come both from the Services and Research branches of the Office. A recent analysis indicates that, taking the computing facility as a whole, 25 per cent is used for operational work—routine numerical forecasts and allied tasks—19 per cent by Services branches and 56 per cent on research. Computing resources available after first meeting operational requirements are distributed under a carefully controlled allocation system, the amounts used being monitored in some detail daily. Any computing time left over when all the fixed allocations have been met is made available to users on a first come, first served basis, and this extra allocation is relied on to carry out long-running computations by some Research branches.

The new powerful scientific processor

The installation of a powerful new processor will require that particular attention be given to ensuring the continuity of services, ranging from operational forecasting to the provision of climatological information now based almost entirely on central computer support. It has been decided that the new processor should be installed in a location immediately adjacent to the two IBM computers and much effort was devoted during the year to planning the changes in accommodation and new construction work entailed, in collaboration with the Property Services Agency. By the end of the year these plans had been finalized and work had started with a view to installation early in 1981.

The acquisition of the new computer will entail the specification of the types of program appropriate to the new processor and the training and guidance of programmers in its use. The ability of the new machine to perform mathematical and other operations on sets of numbers instead of handling them individually will necessitate a different approach to the formulation of many problems. Changes may be needed in some of the service programs such as those

concerned with forming or accessing the synoptic data bank, while ensuring that there is a minimum of disturbance to users of such facilities. The operational procedures for running a new routine analysis/forecast cycle with appropriate back-up arrangements will need to be devised. All these matters were the subject of detailed study as the year ended.

The computing network

The existing computing facility continues to develop and already forms quite a complex network. Remote Job Entry (RJE) links were established with the Exchequer and Audit Department and with the Greater London Council. The latter make use of their terminal to extract wind data for use in a storm surge model designed to study the probable response of the Thames barrage in potential flooding situations. The maintenance of the links between COSMOS and local computers in the Principal Forecasting Offices at London/Heathrow Airport and HQ Strike Command require a reliable communication control system with full back-up. Plans are being made to install a suitable controller for these and other terminal devices which could handle much of the present and planned network as an integrated system.

Optimization of the system

A small team of computer scientists, working in collaboration with the manufacturers, is responsible for writing software and adapting standard software packages to meet the Office's special requirements. Following much development work by this team and a series of operational trials a new operating system, Multiple Virtual Storage (MVS), with an associated job-scheduling procedure, Job Entry Sub-System 3 (JES 3), was introduced in May. The new system is better equipped to handle the changing work-load over the next few years and its introduction was essential to maintain the flexibility of the network as a whole during a period of rapidly developing technology. Inevitably some problems relating to the particular needs of the Office were encountered in the first few months after introduction. Some 3000–5000 of the jobs previously run on the 370/158 each month have now been transferred to the 360/195 to enable more of the capacity of the former (front-end) machine to be devoted to controlling the network and the flow of jobs through the coupled system. The change in work-load on the 360/195 has resulted in less-efficient usage of the central processor unit (CPU), since fewer long-running computations making heavy use of the CPU can be accommodated. Nevertheless the CPU on this machine is still in use for about 14 hours a day and the software team has continued to optimize the system with a view to improving the service to all users.

The training courses in computing held at the Meteorological Office College have helped in filling vacancies and the Data Processing Branch has assisted by providing instructors for such courses. Assistance in programming techniques is also provided to programmers both in regard to particular problems channelled through the Enquiry Bureau and through the production of bulletins of general application. The 'Programming Techniques Guide' has been reviewed and amended in the past year in the light of changes in the operating system introduced during the year.

Support for computer-based applications

The graphical presentation of data to forecasters has now been almost completely automated. The higher quality achieved by the Calcomp 960 flat-bed plotters has facilitated their wider use, with consequent improved efficiency, and 100 charts a day are now produced on them. Altogether over 100 000 plotted charts, tephigrams, contour charts and other diagrams were produced during the year for operational purposes alone, on either paper or microfilm. Modifications to the software have led to a saving of 10 per cent in CPU time and have increased the adaptability of the programs, some of which are purchased by outside agencies. An invention by a staff member of a miniature inner cassette for the microfilm plotters has halved the amount of film wastage caused by the high proportion of short runs. Most of the charts produced for operational purposes are used by forecasters at Headquarters, but many are also transmitted by facsimile to outstations. It is hoped to achieve some improvement in efficiency in the latter process by handling the chart data in digital form and programs have been written to produce facsimile output direct from the plotting modules. When this can be injected directly into the facsimile transmission system there should be worthwhile benefits in reduced handling delays and improved clarity.

Observations of a special nature were received at Bracknell via the Global Telecommunication System (GTS), during the two special observing periods of the First GARP Global Experiment (FGGE). These included measurements from drifting buoys, constant-level balloons and aircraft drop-sondes. These were processed and deposited in the synoptic data bank, and were subsequently accessed for use in obtaining global analyses. An intensive effort was needed to keep up to date the data-bank procedures. Additional new information included measurements of sea surface temperature from Meteosat and hourly rainfall reports. Modifications were also made to the data-bank programs to allow for changes in the operating system and to correct errors associated with particular configurations of data.

Data management for the First GARP Global Experiment

The Data Processing Branch was responsible during the year for processing certain surface-based reports as part of the UK contribution to the data management plan for FGGE. The reports concerned were those originating from WMO Regions I and VI, comprising countries in Europe, Africa and parts of the Middle East, and also included all ship observations received at Bracknell. Throughout the year, surface-based observations from the above countries were sent to Bracknell by post on magnetic tape or punched paper tape to arrive within two months after observation time. These sets of observations were then merged with collectives of reports which had been received in real time on the GTS. The resulting composite data sets were processed and dispatched on magnetic tape to the Surface-Based Data Centre at Obninsk, USSR, to arrive not later than 90 days after observation time.

Though the surface-based observations constitute the main part of the FGGE observing system, other designated data centres were also provided with reports. The Special Aircraft Data Centre in De Bilt, Netherlands, was supplied with observations taken automatically from British Airways Boeing 747 and Concorde aircraft during scheduled flights, while ship observations have been

sent to the Mobile Ship Data Centre, Hamburg. All these observations will eventually be combined as a FGGE archival data set and deposited in the World Data Centres in Washington and Moscow for subsequent use in studies of the general atmospheric circulation.

Storage and preparation of data

The processor-controlled keying (PCK) installation exists to transcribe meteorological records such as surface and upper-air climatological returns, rainfall observations, etc. to a form which can be processed on the COSMOS system. These data are later processed into a permanent archival record. The observations are keyed by hand at 19 stations which are connected to a small computer, and are recorded on magnetic tape. A system is now being implemented to transfer data direct into COSMOS from PCK. Various methods of reducing dependence on this rather cumbersome procedure for handling climatological data are being considered. Automatic extraction of some of the data received over telecommunication channels and statistical quality-control procedures to reduce the present verification process are two such methods. Located with the PCK installation are operators who provide a punched-card service for programmers. These staff members handle the large card-punching tasks, smaller tasks and corrections being dealt with by the programmers themselves.

Systems Development

The major responsibilities of the Systems Development Branch are to investigate areas in which computer techniques might effectively be applied and to co-ordinate all the subsequent arrangements for the implementation of appropriate systems. The development of machinable archives continues to be the largest single task. In general, proven systems, whether they are composed of hardware, software or both, are transferred to the principal, usually operational, user who is therefore enabled to provide an improved service. One section of the Branch runs the DEC PDP 11/40 mini-computer facility which is used routinely for data transcription but is also used as an experimental test-bed.

Procurement of powerful rear-end processor

In November an order was placed with Control Data Limited for the supply of a CYBER 203E computer to be attached to the main COSMOS configuration (see page 61 for a description of COSMOS). It is expected that the new computer, which will be installed early in 1981, will be at least ten times the power of the IBM 360/195 when used on specialized numerical modelling work. The increased computing capability will allow the Office to play an important role in the numerical modelling work involved in the World Climate Program. Another major application will be the development and operational running of a mesoscale model for both Defence and Public Services requirements. The new machine will also allow extensions and improvements to be made to the main operational numerical forecasting model and will permit the inclusion of numerical modelling techniques in the further development of the monthly forecasts.

Automation of selected functions at major outstations

The computer-based system to be installed at the Principal Forecasting Office (PFO) at London/Heathrow Airport was finally ordered in September after problems with the specification of suitable visual display units (VDUs) for graphical work and difficulties over accommodation had led to some delay in placing the order. The equipment is due to be delivered to Bracknell early in 1980 and will then be assembled into a complete system for testing prior to being installed at Heathrow later that year.

Action to obtain similar equipment for PFO HQ Strike Command started in November. A similar system is to be obtained by the Directorate of Naval Oceanography and Meteorology and will be installed at the Fleet Weather and Oceanographic Centre, Northwood. Discussions were held with staff from the Public Services Branch and London Weather Centre (LWC) to finalize the detailed requirement for a similar system for LWC.

In all these systems the main task will be the automatic plotting of basic observations and the presentation of forecast products in line-drawn form. Flexibility in the selection and order of transmission of data from Bracknell will be provided by establishing medium-speed (2400 or 4800 bits/second) data links to the central COSMOS data banks.

Computer-based data archives

Good progress has been made in the development of systems for archiving machinable data in the last year. Nearly all contemporary data are now acquired, subjected to quality control and placed in archive storage as routine. Treatment of the backlog of manuscript data continues to be a major task. However, there are now just a few clearly identifiable gaps to be filled rather than massive omissions from the data base.

Despite the use of high density (6250 bits/inch) magnetic tape for storage the need for a mass storage system is clear. Ideally a store should provide easy access to a very large data base and also provide records that can be kept, in proper conditions, for centuries with a minimum of attention. Accordingly, discussions have continued with manufacturers of potentially suitable devices.

Alternative methods of capturing data for the climatological archive have been investigated. At present many of the data are returned on standard forms in manuscript for data entry via the processor-controlled keying (PCK) installation (see page 64). An experiment was started to investigate the feasibility of using data transmitted over the normal telecommunication channels. This possibility should become an acceptable scheme when the new reporting codes (see page 70) are introduced in 1982. These provide for greater precision in recording variables such as temperature. Studies of the suitability of optical character-recognition techniques were also continued.

Study of administrative systems

Many aspects of the work of the Personnel Management and Supply and Finance branches involve repetitive, routine work that might be amenable to handling by computer. The Branch therefore commenced a fairly detailed study of the extent to which the use of computers could assist in the maintenance of personnel records, modelling in the manpower planning field, production of routine documents associated with staff changes, management accounting, overtime analysis, stock control, word processing, photo-typesetting and

management information services. The first report on the study completed at the end of the year identified several useful applications which could result in increased efficiency as well as techniques which might allow effective implementation. The need, in some applications, for a fast and effective system for man–machine interaction which would also be of value in speeding up the handling of meteorological enquiries, was identified.

Other systems studies

The Branch gave advice and assistance with a number of computer procurements during the year. An order was placed in December for a small computer system for the Meteorological Office College. This will be linked to COSMOS and used to assist in the training of programmers. Provision has been made for future enhancement of the system to allow selected jobs to be run at the College to give training appropriate to staff at major outstations equipped with small computers. Advice was also given to the Meteorological Research Unit, Cardington, and an Operational Requirement was prepared for a computer to be used for local data analysis and to provide a connection to COSMOS using Remote Job Entry. Studies of terminals or computers to assist in the work of the office at Edinburgh have also been undertaken.

Satellite imagery was processed on a semi-operational basis throughout the year by the PDP 11/40. A new dedicated system was delivered in November and will be brought into fully operational use during 1980. TIROS-N and NOAA-6 images were produced on a polar stereographic projection and Meteosat pictures were also processed. Particular use was made of two adjacent visible wavelength images from Meteosat, in composite form, in televised weather presentations. The supply of Meteosat data in digital format to the Meteorological Office Radar Research Laboratory was increased by the provision of visible-wavelength as well as infra-red imagery.

The data transcription service handled an increased volume of data recorded on non-standard media (see Table XIV) and programs were written for new applications. Difficulties were encountered with the transcription of 3M DC 100 A magnetic-tape cartridges because of failures to conform closely with the relevant standards.

Meteorological Telecommunications

The Telecommunication Branch is responsible for the provision of general communication support to the whole Office, for the operation of the main Meteorological Telecommunication Centre (Met TC) located at Bracknell, and for the organization of the complex networks of lines through which information vital to the provision of meteorological services is collected and distributed. Meteorological observations of many kinds, including those derived from meteorological satellites, have to be collected and exchanged, and analyses and forecasts based upon them widely disseminated. All this must be done speedily and with a high degree of reliability. The use of computers (including microprocessors) for the handling of information continues to increase, and this requires accuracy to be maintained both in the format and in the content of messages. Detailed control procedures and careful monitoring are necessary to ensure this. During 1979 the volume of information handled again increased

considerably. There were improvements in the provision of cloud imagery from satellites and in the supply of data by teleprinter to the outfield. Plans for further improvements were approved.

As a Regional Telecommunication Hub (RTH) on the Main Trunk Circuit (MTC) of the WMO Global Telecommunication System (GTS), Bracknell has responsibility for the link between Europe and North America and for the dissemination of traffic to a number of National Meteorological Centres (NMCs) in northern Europe. The MTC connections are to the Paris RTH and to the World Meteorological Centre (WMC) in Washington. These circuits operate automatically, transmissions of digital data at 2400 bits/second alternating with transmissions of pictorial information in analogue mode. A Main Regional Circuit between Bracknell and Offenbach operates in a similar fashion. The regional circuits to the other NMCs generally operate in digital mode only and transmissions of pictorial information are made over separate facsimile networks. Bracknell RTH is responsible for the collection of observational data from Greenland, Iceland, Gibraltar, the Netherlands, the Republic of Ireland and the weather ships of the North Atlantic Ocean Stations (NAOS) network, as well as from the United Kingdom itself. Messages containing these data are distributed from the Bracknell RTH via the MTC and the European Meteorological Telecommunication Network (EMTN) to meet the needs of Europe and other parts of the world.

The Met TC forms the central hub of an extensive network of teleprinter and facsimile circuits by means of which Bracknell is able to fulfil its role as the NMC for the United Kingdom. Observational data and processed information are collected and distributed and, in addition, pictorial information from meteorological satellites is received over a direct connection from the Royal Aircraft Establishment (RAE) satellite ground station at Lasham and distributed over a dedicated facsimile network (SATFAX). The development of these services, using data and imagery from the European geostationary satellite Meteosat and the United States polar-orbiting satellites TIROS-N and NOAA-6, has been an important feature of the year's work and plans for the extension of the SATFAX network and the establishment of a mini-computer system dedicated to the processing of satellite cloud imagery are referred to later. A network of land-lines connecting Bracknell with the mainland of Europe and with Ireland and Iceland provides for the distribution of Washington and Bracknell analyses and forecasts (including Area Forecast Centre products) by analogue facsimile to Norway, Denmark, the Federal Republic of Germany, the Netherlands, Ireland, Iceland, France, Italy and other countries. For centres not linked to the land-line network, two radio-facsimile broadcasts and a radio-teleprinter broadcast provide for the transmission of pictorial and alphanumeric information. Facilities exist for the reception of similar radio broadcasts, both from neighbouring RTHs in Europe and from more remote centres, so that some limited exchange of data to support essential services can continue even if there are major failures in the land-line networks. The Met TC is operated in accordance with agreed international and national procedures for the collection and distribution of meteorological information on global, regional and national scales and members of the Branch play an active role in the international working groups which study the requirements and formulate these procedures. Many of the functions of the Centre are already automated and this trend is continuing, placing considerable demands for planning, operating and organizing on the

telecommunication staff, engineers and meteorologists, who together compose the staff of the Telecommunication Branch.

Bracknell Automated Telecommunication Complex

The twin Marconi Myriad II message-switching computers, on which all operations in the automated complex (AUTOCOM) are based, control the operation of the MTC circuits to Paris and Washington (at 2400 bits/second), the regional circuits to Offenbach (2400 bits/second), Oslo, De Bilt and Dublin (1200 bits/second), and many low-speed (50 bauds) teleprinter circuits including links to Brussels, Rheindahlen, Hilversum, Reykjavik, Gibraltar, Cyprus, 11 data collection centres and about 100 other offices in the United Kingdom. An IBM System 7 computer is used to control the transfer of data between AUTOCOM and the main data-processing computer system (COSMOS). The 1200 bits/second link to the new automated message-switching system in Dublin became operational during the year, but the service on low-speed circuits had to be restored for a period late in the year while the Dublin equipment was moved to a new location.

Traffic handled in AUTOCOM continued to increase during the period, mainly as a result of the First GARP Global Experiment (FGGE), the operational phase of which ran from December 1978 to November 1979. Not only were world-wide efforts made to improve coverage from existing observational networks, but a number of special FGGE projects (such as the Drifting Buoy System and the Tropical Constant-level Balloon System) were also developed, and there was a very considerable increase in the amount of observational data (not only cloud imagery) which became available from both polar-orbiting and geostationary satellites. In addition, greater efforts devoted to monitoring the operation of the World Weather Watch (WWW), including the GTS, led to a significant improvement in data capture from many parts of the world. Following the recommendations of the WMO Commission for Basic Systems (CBS), confirmed at the Seventh Session in November 1978, steps were taken to increase the number of analyses and forecasts made available by WMCs and RMCs for distribution via the GTS in WMO GRID code. As a result, to meet the needs of Europe (including those of the European Space Operations Centre (ESOC) at Darmstadt), more than 300 GRID bulletins per day from the WMC Washington were handled by the Bracknell RTH for most of the year. In addition, the output from Bracknell, both for aviation flight planning and for general meteorological purposes, was increased.

The additional traffic caused overloading of the Marconi Myriad system and it became necessary to ask associated NMCs like Oslo, De Bilt and Reykjavik to accept some reductions in the traffic they received. Much time and effort had to be devoted to optimizing the operation of the system by introducing carefully controlled changes in the operating software and in maintaining the overall serviceability of the system, a task to which technicians of the Maintenance Organization also made a significant contribution. New equipment to enhance the system was not delivered until April and this was followed by a long period of testing and operational integration which was still continuing at the end of the year.

Facsimile services

There were no major developments during the year apart from an increase in the number of COSMOS products distributed by analogue facsimile to major outstations such as London Weather Centre, where wind and wave forecasts are of special value in connection with the provision of services for the North Sea offshore industries. In the outfield the use of document facsimile (DOCFAX) continued to increase, mainly in support of forecasting services for commerce and industry arranged by the Public Services Branch. Development work on digital facsimile continued during the year, particularly in the use of digital methods to provide automatically plotted charts directly from COSMOS to the Meteorological Office land-line facsimile service (MOLFAX). The work involved co-operation between the staffs of the Telecommunication and Data Processing Branches. A method of passing the charts from COSMOS to AUTOCOM was developed. From there the charts can be relayed to an Argus 700 mini-computer for temporary storage. It remains to develop an interface with the operational facsimile system so that the charts can be withdrawn from the store as required, converted to analogue mode and fitted into the transmission schedule.

Satellite data reception and distribution

The RAE satellite ground station at Lasham provided cloud images on a routine operational basis throughout the year. The quality of imagery from the European geostationary satellite Meteosat improved considerably and an agreed selection of geostationary and polar-orbiting satellite cloud pictures was distributed via the SATFAX network. The service had to be reduced following a serious failure of Meteosat in November, when the production of cloud imagery and derived wind data ceased. Restoration of the full service may have to await the launch of Meteosat II which will not be before the autumn of 1980. The United States polar-orbiting satellite TIROS-N, launched late in 1978, took over the provision of imagery when NOAA-5 was taken out of service, and the service was extended following the launch of the second satellite in the new series (NOAA-6) in the summer. By September both Scanning Radiometer (SR) imagery and selected Advanced Very High Resolution Radiometer (AVHRR) sectors were available for distribution from both polar-orbiting spacecraft.

A special computer system dedicated to the processing of satellite imagery was delivered late in the year and will be used, next year, to provide an operational service based on the techniques which have been developed in the Systems Development Branch. The system includes special television-type displays for use in the Central Forecasting Office (CFO), and has the capacity to generate picture sequences of interesting cloud developments. It will also be used to transform cloud imagery to map projections suitable for direct comparison with the forecasters' normal working charts. To make some of these products more generally available, an extension of the existing SATFAX network is planned and will begin to be implemented early in 1980. The new system will also supply cloud pictures to BBC Television.

The geostationary and polar-orbiting satellites both provide facilities for the acquisition of observational data from suitable Data Collection Platforms (DCPs) and a number of schemes based on these were in operation during the year. In one of them, four experimental DCPs established by water authorities in the United Kingdom were interrogated by Meteosat, and bulletins containing

their observations were sent via the GTS from ESOC at Darmstadt to Bracknell, where the messages were transferred to Telex for onward transmission to the DCP operators. The experiment confirmed that observations can be acquired by this means very quickly. The service would be even quicker, with response times of no more than a few minutes, if the authorities concerned were to establish a Primary Data User Station (PDUS) for acquisition of the observations direct from the satellite.

Developments in the low-speed telegraph networks

The continued growth in traffic in recent years has led to increasing difficulties in the distribution of basic observations and processed information to stations in the United Kingdom, particularly via MCC1, the basic 50-baud teleprinter broadcast. The difficulties particularly affected those stations (about half those in the United Kingdom) where the MCC1 broadcast is interrupted for 15 minutes around the hour to enable observations to be collected, area forecasts to be issued and so on. To alleviate these difficulties, a specially compressed version of MCC1 was introduced. By means of a twin Gimini microprocessor system, two 50-baud outputs from the Myriad system in AUTOCOM were combined to form a single 50-baud transmission. This not only provided additional facilities for arranging bulletins in the most acceptable priority order, but also enabled many of the spaces between bulletins, and superfluous characters included in the full WMO format, to be reduced or even eliminated. The result is a highly efficient arrangement which saved about 20 per cent on transmission time and considerably reduced delays on MCC1.

However, further improvements are already needed and the situation will become untenable when the new WMO common code for surface synoptic observations comes into use on 1 January 1982. There will then be a considerable increase in the length of bulletins containing surface observations and this would result in unacceptable reductions in the volume and timeliness of the distribution of information on low-speed circuits. To overcome this problem and, at the same time, keep costs to a minimum, a scheme was devised to replace the 50-baud domestic teleprinter broadcasts MCC1 and MCC2 with 100-baud transmissions operating in the present MOLFAX facsimile circuits. The scheme will involve the use of frequency multiplexing techniques, so that the analogue facsimile transmissions and two 100-baud telegraph channels can be accommodated in the existing circuits. The required 100-baud transmissions will be provided by combining at least three 50-baud outputs from the existing system, using microprocessor techniques similar to those used for the compressed MCC1 broadcast.

The first AUTOPREP terminal was delivered to Bracknell in the autumn, several months behind schedule. AUTOPREP, which comprises a visual display unit and keyboard, supported by storage and format-generating facilities, will be installed at a number of important meteorological offices in the United Kingdom, as well as in the Bracknell Met TC. Its initial role will be to facilitate the collection of basic observations and other information from the outfield, and their transmission to Bracknell. The terminals will also provide facilities for the compilation of standard messages containing forecasts and other information for distribution to the BBC, public utilities, the Press and other agencies. In some cases direct connection to the Post Office Telex system will be included.

Other telecommunication network developments

Work has continued on the development of the telecommunication link between AUTOCOM and the European Centre for Medium Range Weather Forecasts (ECMWF), using a new line protocol system based on the X-25 standard. At the Bracknell end of the link a Ferranti Argus 700E computer has been used to test the new line procedures, first with the ECMWF contractor in London and, later in the year when the equipment had been moved to the operational site, with ECMWF at Shinfield Park near Reading. To enable ECMWF to inaugurate their operational forecasting system in July, a twice-daily service was provided, involving the transport by road of magnetic tapes containing all the information received in the Bracknell RTH. Towards the end of the year, to allow ECMWF to test their new telecommunication system, experiments were carried out in which the magnetic tapes were read into the Argus 700E computer operating the link, thereby avoiding the need for their transport by road and enabling the ECMWF data bank to be replenished more frequently.

To provide a permanent high-speed interface between AUTOCOM and COSMOS, special Teleprocessing Units (TPUs) are being developed. The basic hardware modules (twin Ferranti Argus 700G mini-computers) were acquired and special studies were carried out by two software houses as to how the rest of the work should be implemented. Ultimately the TPUs will also be used to serve the automated systems to be established at London/Heathrow Airport, Headquarters RAF Strike Command, and other important offices.

INTERNATIONAL AND PLANNING

The Meteorological Office has continued to play a leading role in international co-operation which is essential for the operation of weather services and their development. This co-operative aspect was highlighted during the year by the meeting in May of the Eighth World Meteorological Congress in Geneva. Congress is the governing body of the World Meteorological Organization (WMO); it meets every fourth year to review policy and organization and to formulate plans for the development of meteorology in the service of mankind. Preparation of the United Kingdom brief for Congress was the major preoccupation of the Branch in the early part of the year. The United Kingdom delegation was led by the Permanent Representative, Dr B. J. (now Sir John) Mason, Director-General of the Meteorological Office. The United Kingdom delegates were active both in the major committees and in various sub-groups. One of the major concerns of the United Kingdom was to ensure a 'no real growth' budget, while maintaining the momentum of aid to the developing countries. The outcome of this and other decisions of Congress were satisfactory to the United Kingdom. Dr A. C. Wiin-Nielsen, of Denmark, Director of the European Centre for Medium Range Weather Forecasts, was elected to succeed Dr D. A. Davies, of the United Kingdom, as Secretary-General. Dr Davies, who has served with distinction for the last 24 years, was awarded the honorary title of 'Secretary-General Emeritus' in recognition of his long and valued services.

Dr Wiin-Nielsen's appointment takes effect on 1 January 1980. Sir John Mason was re-elected to the Executive Committee (EC) which is responsible to Congress for the implementation of the WMO program and Congress decisions. The Executive Committee meets annually, the first meeting of the newly elected

EC following immediately after Congress. Sir John was supported at this meeting by Mr G. J. Day, Assistant Director (International and Planning).

In addition to Congress and the Executive Committee, WMO has six Regional Associations which meet every four years. The United Kingdom is a Member of Regional Association VI (Europe) and Regional Association I (Africa); both Regional Associations last met in 1978. The United Kingdom is also represented on each of the eight Technical Commissions established by Congress to study and make recommendations on particular aspects of meteorology.

International co-operation was also the keynote at the Commonwealth Meteorologists' Conference (CMC) which met at the Meteorological Office College, Shinfield Park, near Reading, in June. The CMC meets every fourth year at a time conveniently close to Congress. This year it was attended by Directors or other representatives from 20 Commonwealth countries and was opened by Mr Geoffrey Pattie (Under Secretary of State for Defence for the Royal Air Force). A Government reception for the Delegates was held at No. 1 Carlton Gardens. By tradition the Conference, which was first held after the war of 1914–18, is a forum for an informal exchange of views on predominantly scientific questions, discussion usually being based on papers by specialists from the Meteorological Office. Included in the program were visits to Beaufort Park and the Headquarters building. The final session of the Conference was devoted to the WMO Voluntary Co-operation (formerly Assistance) Program (VCP) and the Director-General reaffirmed the commitment of the Office to continuing aid to developing countries, particularly to Commonwealth countries in Africa. The organization of the Conference and the secretarial support were undertaken by the International and Planning Branch with the valuable co-operation of the Meteorological Office College.

The global systems for observation, collection, dissemination, storage and retrieval of meteorological data compose the World Weather Watch program of WMO. In recent years the Meteorological Office has extended the network by the establishment overseas of a number of stations making surface and upper-air observations. Meteorological Office staff serve at several of these stations but there are plans for some of them, located in independent countries, to be replaced by locally recruited staff in the course of the next few years. St Helena, however, a small island in the South Atlantic, is a Meteorological Office station, manned by volunteer officers from the United Kingdom who do an 18-month tour of duty, assisted by locally engaged observers. Unlike other Meteorological Office stations overseas St Helena does not enjoy the support of the Royal Air Force; indeed there is no airfield on the island and the only means of access is by the RMS *St Helena* which makes the round trip from Avonmouth to Cape Town via St Helena about every two months. The telecommunication link to Kano, Nigeria, is now operational and St Helena observations are regularly passed along it. For the time being, because of the difficulties at Kano in transmitting data on the Global Telecommunication System (GTS), St Helena continues to send observations by other routes as well. The coral atoll of Aldabra in the Indian Ocean is almost equally isolated; a Meteorological Office volunteer observer serves there with the Royal Society Research Station. With the closure of the Research Station in 1980, responsibility for observations will be assumed by the Seychelles (to which Aldabra belongs). The WWW upper-air station at Mahé in the Seychelles continues to be supported by the United Kingdom, financially and by the secondment of two UK officers as officer-in-charge and

technical officer. Both posts are expected to be taken over by Seychellois staff during the course of the next two or three years.

The dissolution of the South Pacific Air Transport Council (SPATC) in September necessitated making new accounting arrangements for the UK-supported WWW stations at Tarawa (Kiribati, formerly Gilbert Islands) and Funafuti (Tuvalu). The New Zealand Meteorological Service, which manages both stations, has taken over the accounting function previously undertaken by SPATC on behalf of the United Kingdom. The technical officer post at Tarawa, at present filled by UK volunteers, will be taken over by a locally recruited technician in two or three years' time on completion of his training in New Zealand and in the post. Progress of the New Hebrides towards independence, due in 1980, has resulted in some administrative changes there. The British expatriate officer-in-charge of the WWW upper-air station at Bauerfield, which is supported by equal contributions from the United Kingdom and France, was replaced at the end of his tour by a New Hebridean. The technical officer post continues to be filled by volunteers from the Meteorological Office. The present Agreement between France and the United Kingdom, under which the upper-air station at Bauerfield was established and is operated, will have no force following the transfer of power to the New Hebrides; efforts have been made throughout the year to find a basis on which the station can continue to be funded for a transitional period during which decisions can be made on its future.

Some of the WWW stations mentioned above are in attractive locations but all present problems of one kind or another to UK staff members working there, either because of their remoteness or from the lack of domestic or educational facilities. Thus, we are fortunate to find from our staff a flow of volunteers who, with their wives and families, are prepared to undertake duties and a way of life far more demanding and challenging than any they would be expected to face in a normal career.

The WMO Voluntary Co-operation Program was established as a means by which developing countries could be helped to fulfil their obligations under WWW by donations of equipment and by training and other services provided by the developed countries. Mr G. J. Day, Assistant Director (International and Planning) attended an Informal Planning Meeting of major donors in January to discuss developments and policy. The United Kingdom has continued to play a prominent part in this activity and has recently adopted a policy of seeking a closer involvement with the meteorological services of selected countries, particularly those countries in Regional Association I (Africa) with which there are both historical and personal ties. Following the precedent of last year's visit by a member of the Branch to several African countries, members of the Branch visited Seychelles, Mauritius and Nigeria during the year to discuss problems on the spot and the ways in which aid might most usefully and rapidly be applied. As an example, agreement was reached with both Kenya and Nigeria on steps to reinstate the important telecommunication link between Nairobi and Kano Regional Telecommunication Hubs. The co-operative effort will involve contributions from Kenya, Nigeria and the United Kingdom. In Mauritius the transport of the wind-finding radar, donated through the Voluntary Co-operation Program for use on the island of St Brandon, proved impossible by sea because of reefs; it was eventually delivered by helicopter by courtesy of the US Navy.

After the overthrow of President Amin of Uganda it was learned that the observational network of the country had been partly destroyed. Instruments for a basic network, readily available from Meteorological Office stocks, were quickly assembled and air-freighted to Uganda. A supply of technical books and manuals was also sent. Books and other equipment, surplus to Meteorological Office requirements, have been sent to other countries as a result of needs noted by members of staff looking at local conditions. The feasibility of establishing or extending training facilities in Africa is being studied. In this connection, Mauritius has responded enthusiastically to a UK proposal that it should undertake the training of wind-finding operators and plans are also being made to mount a technical training course in Nairobi using UK equipment and instructors, with a view to similar courses being included in the curriculum of the Nairobi Meteorological Training Centre. Other plans involve a technical inspection service and co-operation with manufacturers in providing an effective technical support for equipment donated by the United Kingdom. A 5-year plan of technical aid by priorities has been developed.

The North Atlantic Ocean Stations (NAOS) Agreement under which the network of ocean weather ships making surface and upper-air observations in the Atlantic is maintained, remains in operation. The Agreement is due to lapse in 1981. By that time the United Kingdom weather ships will be near the end of their useful lives and discussions have continued on whether they should be replaced or give way to alternative observing systems.

The meteorological aspects of other international activities are dealt with through such organizations as the International Civil Aviation Organization (ICAO) and the North Atlantic Treaty Organization (NATO). The International Council of Scientific Unions, in which scientists participate as individuals rather than as representatives of scientific bodies, is responsible together with WMO for the Global Atmospheric Research Program.

The European Centre for Medium Range Weather Forecasts (ECMWF) works in co-operation with WMO. It is staffed by scientists drawn from 17 Member States; a high proportion are from the United Kingdom. The permanent headquarters building at Shinfield Park, near Reading, donated by the United Kingdom, was officially opened by His Royal Highness The Prince of Wales at a ceremony on Friday, 15 June. Mr Jean Labrousse (France), Deputy Director (Operations) has been appointed to succeed Dr Wiin-Nielsen as Director of the Centre when the latter takes up his appointment as Secretary-General of WMO.

The 12-month operational phase of the Global Weather Experiment was completed in December. The assembly and analysis of the unique data set produced will occupy meteorologists for several years. The Meteorological Office continues to be closely involved in this unique international collaborative effort as reported elsewhere in this *Report*. Assistance was provided for certain African Members to meet their obligations by the provision of consumable items such as radiosondes and balloons, particularly during the Special Observing Periods.

British contributions to Antarctic meteorology are the responsibility of the British Antarctic Survey (BAS) which maintains a program of surface and upper-air observations. Meteorological Office support for the BAS World Weather Watch stations is a continuing commitment but was increased to permit an expanded program during the Special Observing Periods at Faraday and Halley Bay.

The Branch constantly engages in a number of minor, though significant, activities in the field of international co-operation. In July, in response to an urgent request from Zambia, a consignment of electrosensitive facsimile paper, required for meteorological services in connection with the visit of Her Majesty The Queen and the Commonwealth Conference, was despatched within 24 hours. Arrangements were made early in the year for an engineer from Spembly Ltd to visit Romania to advise on modifications to their APT equipment (donated by the United Kingdom under VCP) for the reception of Meteosat data. In the interests of improving the serviceability of radar wind-finding equipment supplied by the United Kingdom under VCP a meeting was held with representatives of the manufacturers (Plessey Ltd). Arrangements were made for improving the monitoring of the performance of equipment and for a quicker response in terms of technical advice and the supply of spare parts.

The Program Review Committee (PRC) met in February and agreed a reduced program of meetings timed to follow closely the making of routine financial reports. A later meeting, planned for October, was postponed to allow the PRC to take note of the effect of changes in Government plans. During the year the Branch devoted a considerable time, in its role of support to the PRC, in an exhaustive analysis of the effort involved, in terms of manpower and finance, in a number of selected projects.

F. H. BUSHBY
Director of Services

STATISTICS OF THE SERVICES DIRECTORATE

The quantitative analyses in this section are intended to provide an indication of the distribution of work within the Directorate of Services and of the extent of the services provided.

TABLE I — NUMBERS OF OFFICES OF VARIOUS TYPES STAFFED BY THE METEOROLOGICAL OFFICE AND OPERATING ON 31 DECEMBER 1979

	Within UK	Overseas
Principal Forecasting Offices associated with the RAF	1	—
Main Meteorological Offices associated with the RAF	6	3
Subsidiary offices associated with the RAF	27	4
Observing offices associated with the RAF	4	1
Principal Forecasting Offices associated with civil aviation	1	—
Main Meteorological Offices associated with civil aviation	3	—
Subsidiary offices associated with civil aviation	9	—
Observing offices associated with civil aviation	8	—
Upper-air observing offices	8	1
Public service offices	6	—
CRDF offices	5	1
Port Meteorological Offices	7	—
Offices associated with the Agricultural Development and Advisory Service (MAFF)	4	—
Other offices	28*	2

*Four of these Stations are administered by DR Met O.

Notes

A Principal Forecasting Office meets the needs of aircraft flying over long distances and operates through the 24 hours.

A Main Meteorological Office operates through the 24 hours for the benefit of aviation and normally supervises the work of subsidiary offices.

A subsidiary office is open for that part of the day necessary to meet aviation requirements.

At an observing office no forecaster is available.

An upper-air observing office may be located with an office of another type if this is convenient.

Public service offices are located in certain large cities.

CRDF offices form the network for thunderstorm location.

Port Meteorological Offices are maintained at the bigger ports.

TABLE II — OCEAN WEATHER SHIPS

To meet the United Kingdom obligations under the WMO Agreement for the Joint Financing of the North Atlantic Ocean Stations (NAOS), the Office operated two ocean weather ships. These were employed to man ocean station 'L' (57°00'N, 20°00'W), one of the four stations of the network, each ship spending an average of 24 days on station each voyage. The station was manned for a total of 359.5 days in 1979 and the two ships were on passage for 70.4 days. Two ships from France, one from the Netherlands, one from Norway and five ships from the USSR served at the other three stations.

TABLE III—MERCHANT NAVY SHIPS

A total of about 6900 ships of the merchant navies of the world make and transmit meteorological reports to the appropriate meteorological centres ashore under arrangements co-ordinated by the World Meteorological Organization. Most of them, including British ships, do this on a voluntary basis. Ships which report in full at four specified times daily are known as 'selected ships'; those which report at the same times daily, but in a less complete form, are known as 'supplementary ships'. A number of coasting vessels, lightships, distant-water trawlers and 'auxiliary ships' also make and transmit meteorological observations.

On 31 December 1979 the numbers of British ships reporting were:

Selected ships	465
Supplementary ships (including 9 trawlers)	25
Coasting vessels	49
Lightships (including 1 light-tower)	12
Trawlers	1
Auxiliary ships	6
Total	558

The British Voluntary Observing Fleet includes ships of many shipping companies, and the numbers on the various routes are as follows:

UK to Australasia	23
UK to Far East	31
UK to Persian Gulf	28
UK to South Africa	41
UK to West Indies	16
UK to Atlantic coast of North America	60
UK to Pacific coast of North America	7
UK to South America	10
UK to European ports	79
UK to Falkland Island and Antarctica	2
UK to distant-water fishing grounds	9
World-wide trading	193

During two typical five-day periods, one in June, the other in November, the average daily numbers of reports from ships received at Bracknell were as follows:

	Reports	
	June	*November*
Direct reception from:		
British ships in eastern North Atlantic	108	140
Foreign ships in eastern North Atlantic	97	92
British ships in North Sea	22	27
Foreign ships in North Sea	6	2
Ships in other waters	30	20
Total	263	281
Reception via other countries:*		
Ships in eastern North Atlantic	587	636
Ships in western North Atlantic	284	293
Ships in Mediterranean	58	49
Ships in North Sea	137	147
Ships in Arctic Ocean	88	81
Ships in North Pacific	779	835
Ships in other waters	355	387
Total	2288	2428

*Via the Global Telecommunication System

TABLE IV — CLASSIFICATION OF STATIONS SUPPLYING CLIMATOLOGICAL INFORMATION

For climatological purposes, data are obtained not only from official sources but also from very many stations which are not part of the Meteorological Office. The following table shows the distribution on 31 December 1979 of stations which supply climatological information. The areas and titles of the districts are those used in the *Monthly Weather Report*.

	Stations Supplying Returns							Stations Supplying Autographic Records		
	Observatories	*Met. O. Synoptic*	*Auxiliary Synoptic*	*Agrometeorological*	*Climatological*	*Holiday Resorts*	*Rainfall**	*Sunshine*	*Rainfall*	*Wind*
Scotland, north	1	7	6	2	34	0	340	26	17	17
Scotland, east	0	6	4	12	48	2	532	39	22	13
Scotland, west	1	6	8	2	51	0	503	26	16	16
England, east and north-east	0	7	3	8	21	5	558	29	17	17
East Anglia	0	10	1	14	20	3	484	27	17	13
Midland Counties	0	7	1	13	41	0	1046	40	27	16
England, south-east and central southern	1	13	4	16	30	16	776	56	32	24
England, south-west	0	7	12	5	31	9	617	34	14	14
England, north-west	0	6	1	3	14	2	578	19	22	10
Isle of Man	0	1	2	0	0	1	21	3	1	3
Wales, North	0	1	2	3	13	3	265	11	3	3
Wales, South	0	3	6	7	15	2	342	16	17	7
Channel Islands	0	1	1	0	3	2	18	5	0	3
Northern Ireland	0	2	5	7	49	0	278	26	50	10
Total	3	77	56	92	370	45	6358	357	255	166

*Includes stations in earlier columns.

TABLE V — HEIGHTS REACHED IN UPPER-AIR ASCENTS

The following table shows the number of upper-air ascents giving observations of (a) temperature, pressure and humidity and (b) wind, which have reached specified heights, and the height performance of the largest balloons.

	Number of observations	Percentage of all balloons reaching				Percentage of largest balloons reaching
		100 mb (≈16 km)	50 mb (≈20 km)	30 mb (≈24 km)	10 mb (≈30 km)	10 mb (≈30 km)
(a) *Temperature, pressure and humidity:*						
Eight stations in the UK	5747	91·3	80·7	61·5	14·2	37·7
One station overseas	732	96·4	90·6	76·2	33·2	44·7
One Ocean Weather Station (two ships)	1540	90·5	70·2	47·9	3·3	—
(b) *Wind:*						
Eight stations in the UK	11 575	92·7	74·5	44·1	7·3	38·2
One station overseas	1442	96·0	81·8	50·6	16·0	42·8
One Ocean Weather Station (two ships)	1519	87·3	66·9	43·8	2·8	—

TABLE VI — THUNDERSTORM LOCATION

Number of thunderstorm positions reported by CRDF network:

In 1979	31 242

TABLE VII — METEOROLOGICAL COMMUNICATION TRAFFIC

Almost all the national and international exchanges of meteorological data which are used in the construction of synoptic charts and the production of forecasts are effected by coded messages. The coded messages comprise mainly groups of five figures and there may be from 5 to more than 600 such groups in one message. The messages are exchanged by radio and land-line facilities. In addition there is an exchange, both nationally and internationally, of meteorological information in pictorial format. This information is largely analyses and forecasts derived from processing observational data, but also includes cloud imagery from satellites. The transmission method is analogue facsimile by either radio or land-line.

The following figures give an analysis of the traffic (mainly coded messages and information in pictorial format) passing through the Meteorological Office Telecommunication Centre, Bracknell, for one typical day (24 hours) taken in November 1979 and, for comparison, some corresponding figures are given for one day near the end of 1978.

	In	Out	Total	Total in 1978
	number of groups in one day			
Coded messages:				
Land-line teleprinter and data transmission	906 136	3 420 295	4 326 431	3 590 693
Radio transmission	32 751	210 840	243 591	191 270
Facsimile charts (pictorial format):				
	number of charts in one day			
Land-line transmission	183	986	1169	1208
Radio transmission	101	114	215	215

In general the services provided by the Met TC continue to increase and the total number of groups handled (in and out) shows a considerable increase over the previous year.

TABLE VIII — SPECIAL SEASONAL FORECASTS

There is a need for forecasts of a special type at certain seasons. These are described in *Met O Leaflet* No. 1. The numbers receiving such specialized services are as follows:

	Year	Number of customers	Year	Number of customers
Dry-spell notifications (a summer service primarily for farmers)	1978	133	1979	139
Week-end temperature forecasts (a winter service primarily for industrialists)	1978/79	85	1979/80	96
Winter road-danger warnings (primarily for local authorities)	1978/79	303	1979/80	315

TABLE IX — FORECASTS FOR AVIATION

Forecasting for aviation constitutes the primary function of many of the offices. The Central Forecasting Office, acting as a Regional Meteorological Centre of the World Weather Watch, is mainly concerned with the analysis of the weather situation and with the issue of forecast charts for the guidance of other offices, including the two Principal Forecasting Offices which serve civil aviation from London/Heathrow Airport and military aviation from the Headquarters of RAF Strike Command. The Central Forecasting Office also has a commitment to civil aviation in the provision of wind and temperature charts for use with the significant-weather charts produced by the Principal Forecasting Office at Heathrow and for the transmission of grid-point data direct to the British Airways BOADICEA and APOLLO computers at Heathrow and Prestwick respectively and to the Dutch and Belgian Meteorological Services.

The following figures indicate the numbers of forecasts issued for aviation and the numbers of meteorological briefings that took place during 1978 and 1979. These do not include warnings and routine general forecasts.

	1978	1979
Number of meteorological briefings for		
aviation in the UK	367 932	370 372
aviation at overseas stations	35 948	32 270
Number of aviation forecasts issued for		
aviation in the UK	2 074 070	2 136 717
aviation at overseas stations	220 824	181 837

TABLE X — NON-AVIATION ENQUIRIES

Non-aviation enquiries are handled by six Weather Centres, in London, Manchester, Glasgow, Southampton, Newcastle and Nottingham and the forecast unit at Lerwick Observatory. The function of these offices is to meet the needs of the general public for forecasts for special purposes. Many other forecast offices, established primarily to meet the needs of aviation, also answer requests for forecasts and other weather information from the general public, Press, public corporations, commercial firms, etc. These enquiries, most of which refer to current or future weather, are listed below according to the purpose of the enquiry.

	1978	1979
Total number of non-aviation enquiries	2 107 778	2 186 470
Percentage relating to:		
agriculture	14.1	13.0
building	4.3	4.2
commerce, industry	4.3	4.4
holidays	19.0	16.9
marine matters	13.3	13.6
Press	9.3	9.8
public utilities	8.5	8.9
road transport	10.2	10.2
other known purposes	5.9	5.9
unknown purposes	11.1	13.1

TABLE XI — FLASH WEATHER MESSAGES

FLASH weather messages are passed to the BBC and to most independent broadcasting companies for inclusion in their programs at a convenient break. They are, effectively, warnings of the actual occurrence of weather conditions which might cause considerable inconvenience to a large number of people. The following tables show the kind of weather and areas of the country for which FLASH messages are broadcast and the number issued in 1979.

Area	Dense fog	Moderate or heavy snow	Heavy rain	Glazed frost and icy roads	Severe inland gales
Edinburgh and south-east Scotland	—	3	4	2	2
Glasgow and south-west Scotland	—	4	8	3	1
Belfast and Northern Ireland	—	4	1	1	3
Industrial north-east England	—	5	2	2	4
Industrial Lancashire and Merseyside	2	2	3	5	5
Industrial Midlands	3	8	2	6	1
Bristol and Bath	—	2	4	1	—
South Wales	—	6	10	4	5
London and south-east England	—	8	2	8	1
Plymouth and south-west England	—	4	5	1	4
Yorkshire	—	5	4	2	7
Southampton and Portsmouth	—	3	1	1	1
Totals	5	54	46	36	34

TABLE XII — AUTOMATIC TELEPHONE WEATHER SERVICE FORECASTS

Information Service Centre	Forecast area	Number of calls 1978	1979
Bedford	40 miles radius of Bedford	411 205	341 728
Belfast	Belfast	383 287	393 080
Birmingham	Birmingham	1 214 701	1 361 230
Bishop's Stortford	40 miles radius of Bedford	149 783	165 822
Blackburn	Lancashire, Cheshire, Greater Manchester and Merseyside	319 288	429 050
Blackpool	Lancashire, Cheshire, Greater Manchester and Merseyside	225 162	283 012
Bournemouth	South Hampshire	399 435	470 607
Bradford	Leeds, Bradford, Huddersfield	183 492	258 062
Brighton and Hove	Sussex coast	769 849	928 776
Bristol	Bristol	745 768	1 013 271
Cardiff	Cardiff	755 991	1 215 420
Canterbury	Kent coast	509 942	515 886
Chelmsford	Essex coast	166 002	227 375
Cheltenham	South-west Midlands	165 791	233 701
Chester	Chester and North Wales coast	180 055	237 913
Colchester	Essex coast	263 215	345 968
Colwyn Bay	Chester and North Wales coast	111 333	114 627
Coventry	Birmingham	275 811	444 516
Derby	Nottinghamshire, Derbyshire, Leicestershire	170 942	239 138
Doncaster	Sheffield, Chesterfield, Doncaster, Barnsley	61 632	82 555
Edinburgh	Edinburgh	477 568	510 960
Exeter	Devon and Cornwall	315 634	426 297
Glasgow	Glasgow	777 745	876 963
Gloucester	South-west Midlands	276 167	378 908
Grimsby	North Lincolnshire and Retford area	90 334	128 238
Guildford	London	212 115	255 659
Hastings	Sussex coast	95 957	131 003
Hereford	South-west Midlands	120 098	164 143
High Wycombe	Thames Valley	158 035	240 011
Huddersfield	Leeds, Bradford, Huddersfield	100 354	153 011
Ipswich	Norfolk and Suffolk	226 606	287 656
Leeds	Leeds, Bradford, Huddersfield	496 034	677 974
Leicester	Nottinghamshire, Derbyshire, Leicestershire	329 207	495 256
Lincoln	North Lincolnshire and Retford area	206 688	236 526
Liverpool	Lancashire, Cheshire, Greater Manchester and Merseyside	388 496	433 157
Liverpool	Chester and North Wales coast	54 023	59 532
London	London	4 207 551	5 146 826
London	Essex coast	179 497	227 792
London	Kent coast	226 647	238 438
London	Sussex coast	403 825	426 701
London	Thames Valley	269 341	334 173
London	40 miles radius of Bedford	184 711	215 496
Luton	40 miles radius of Bedford	287 180	297 321
Manchester	Lancashire, Cheshire, Greater Manchester and Merseyside	798 054	858 756
Manchester	Chester and North Wales coast	95 894	97 939
Medway	Kent coast	372 401	329 352
Middlesbrough	North-east England	225 957	396 316
Newcastle	North-east England	534 089	707 229
Newport, Gwent	Cardiff	112 859	185 032
Northampton	40 miles radius of Bedford	57 701	148 804
Norwich	Norfolk and Suffolk	432 653	531 126
Nottingham	Nottinghamshire, Derbyshire, Leicestershire	531 263	786 538
Oxford	Thames Valley	307 310	406 120

Information Service Centre	Forecast area	Number of calls 1978	1979
Peterborough	40 miles radius of Bedford	142 565	184 278
Plymouth	Devon and Cornwall	561 279	643 994
Portsmouth	South Hampshire	475 598	616 258
Reading	Thames Valley	433 776	668 583
Sheffield	Sheffield, Chesterfield, Doncaster, Barnsley	470 898	652 605
Southampton	South Hampshire	612 480	961 035
Southend	Essex coast	337 662	410 777
Southport	Lancashire, Cheshire, Greater Manchester and Merseyside	68 716	84 272
Swindon	Bristol	62 697	89 504
Torquay	Devon and Cornwall	163 430	259 873
Tunbridge Wells	London	123 900	143 701
Total		24 467 679	30 805 870

TABLE XIII — CLIMATOLOGICAL ENQUIRIES

Met O 3, Met O 8, Edinburgh and Belfast receive a number of enquiries relating to past weather, to climatology and to the application of meteorological data to agriculture. The following figures give the total number of enquiries and the percentages of this number in various categories.

	1978	1979
Total number of climatological enquiries	33 283	35 641
Percentages relating to:		
agriculture (farming, forestry, market gardening)		9.9
building and design (including siting)		24.1
commerce (sales, marketing, advertising)		3.9
drainage		1.8
education and literature		4.9
flooding		0.3
heating and ventilation		3.7
industrial and manufacturing activities		5.0
law (damage, accident, insurance)		12.7
medical and health		0.6
Press and information centres		1.7
research		8.0
sport, hobbies, holidays		1.2
transport and communications		2.5
water supplies		7.9
miscellaneous (purpose known)		6.3
miscellaneous (purpose unknown)		5.5

TABLE XIV — DATA PROCESSING

(a) Punched-card installation

Number of cards punched by the Meteorological Office installation ... 324 000

Number of cards punched elsewhere on behalf of the Meteorological Office ... 18 772

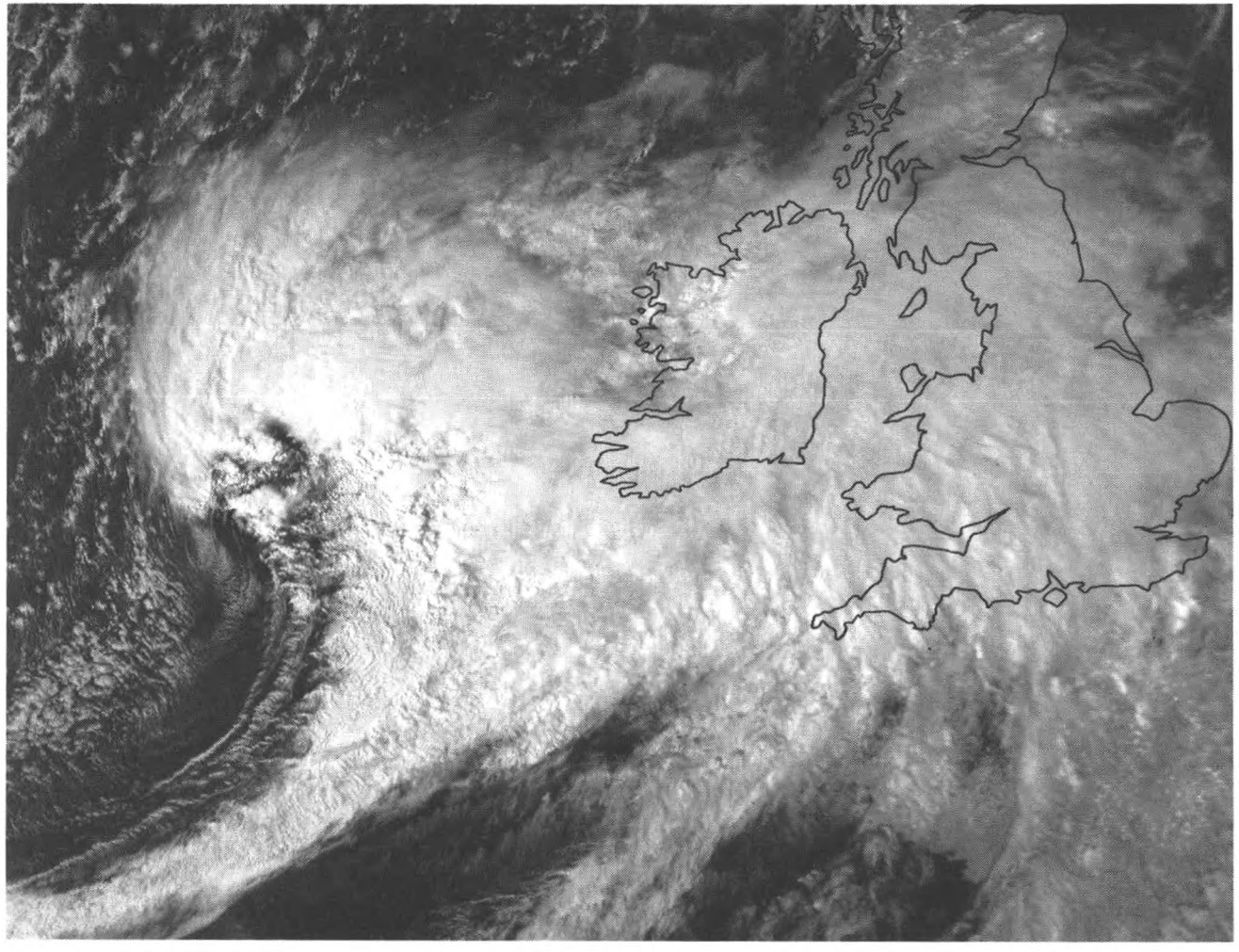
(b) Processor-controlled keying system

The processor-controlled keying (PCK) system was used for data preparation during 1773 hours.

(c) Computer installations

(1) The 360/195 computer was used for computing during 8389 hours.

(2) The 370/158 computer was used for computing during 8488 hours.



Photograph by courtesy of Dundee University.

Polar-orbiting satellite picture for 1537 GMT on 13 August 1979, showing the developing weather pattern south-west of Ireland which subsequently affected the 1979 Fastnet Race.

PLATE I

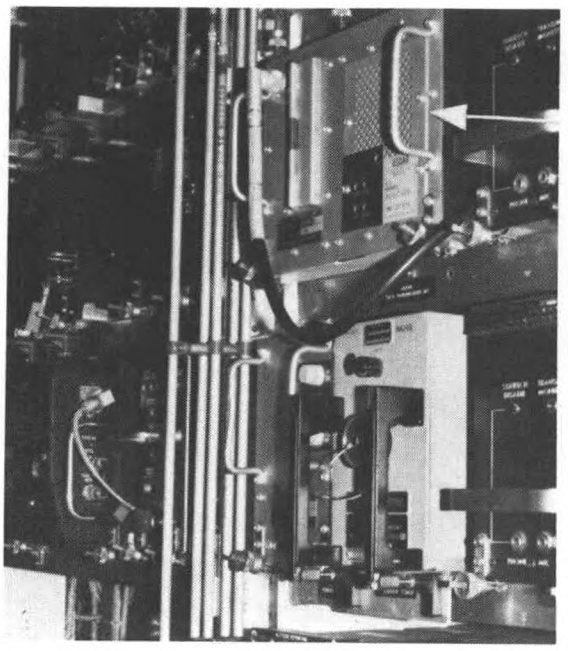
Photograph by RNAS Culdrose.

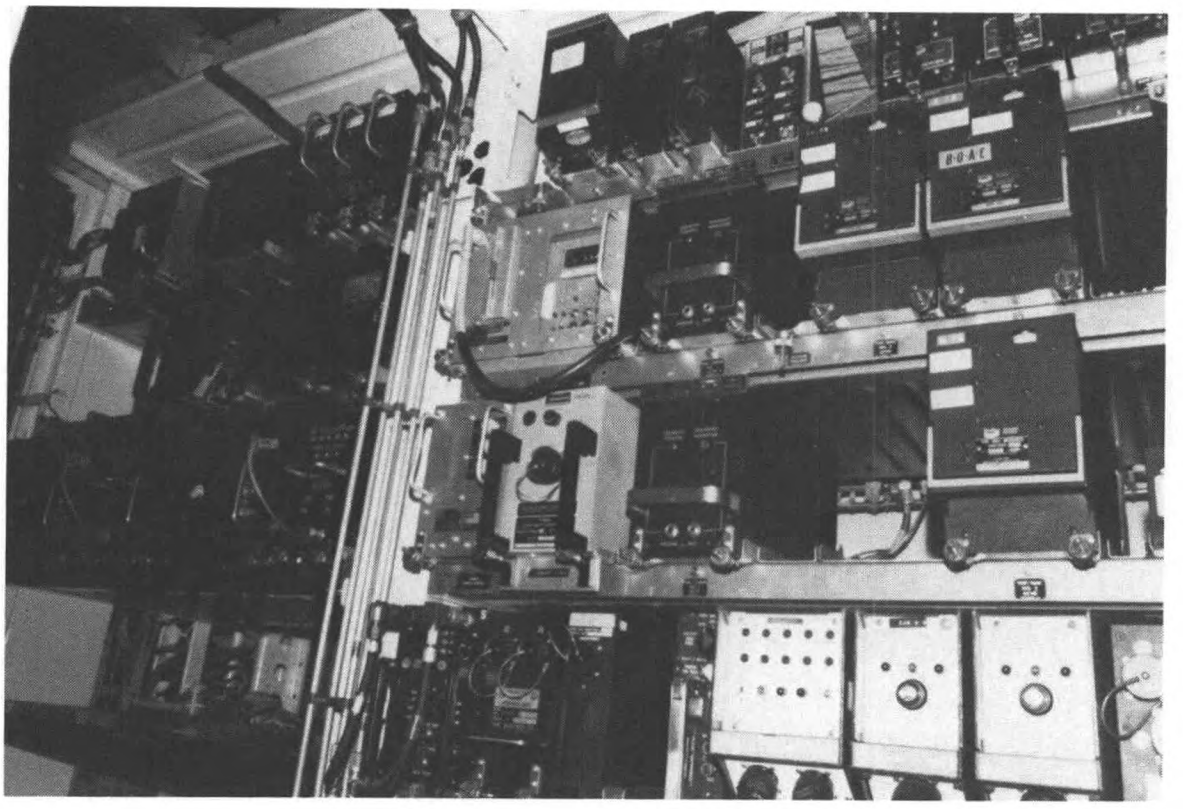
Aftermath—Royal Naval Air Service helicopter over disabled Fastnet Race yacht.

Photograph by courtesy of Conoco.

Conoco's giant Murchison Field base structure lies at anchor in northern waters prior to the upending phase.
Critical 'weather window' conditions, essential to these delicate operations, are well illustrated by the state of the sea.

PLATE IV

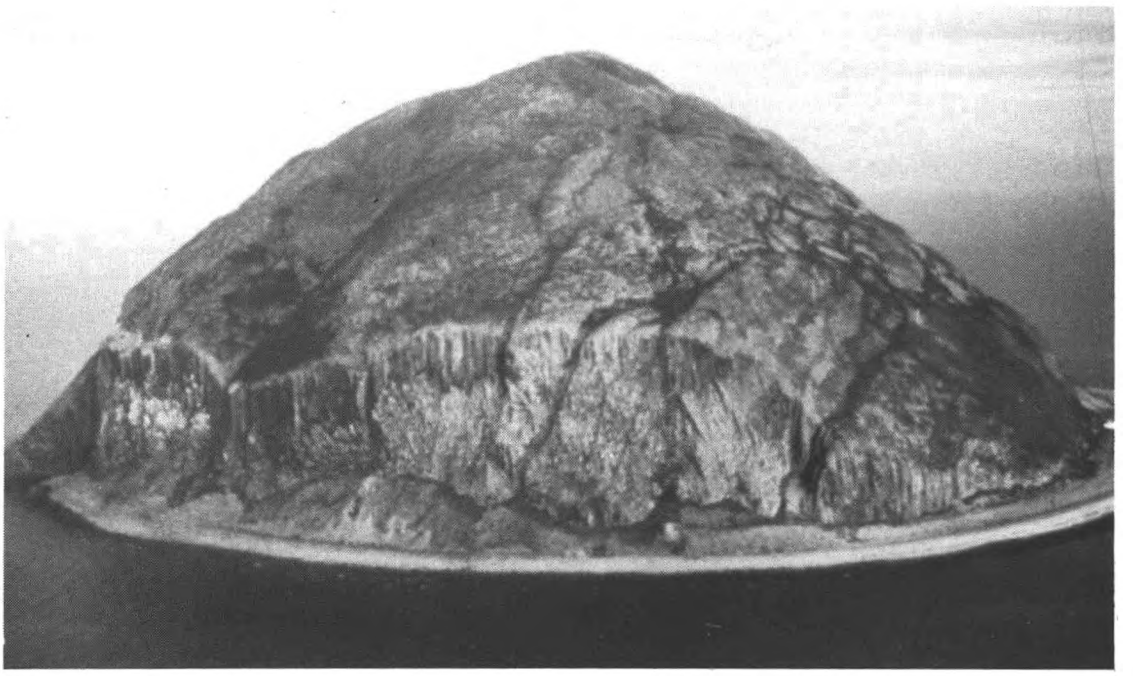




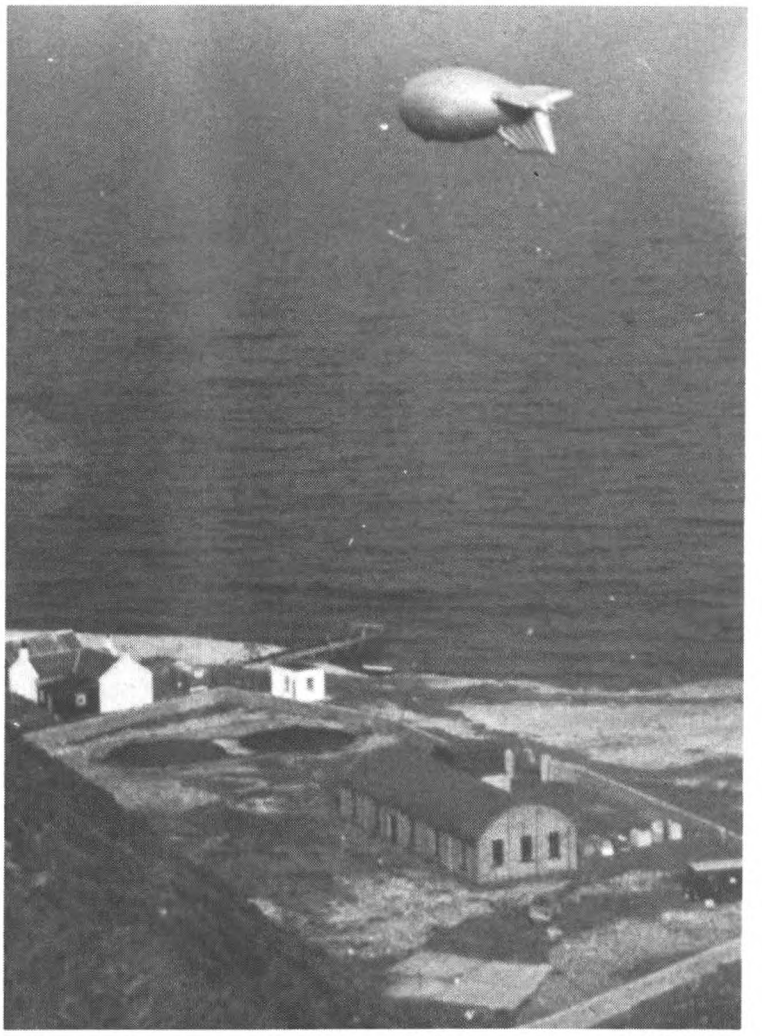
Photographs by courtesy of British Airways.

Aircraft to Satellite Data Relay (ASDAR) equipment aboard one of the two British Airways Boeing 747s so equipped.

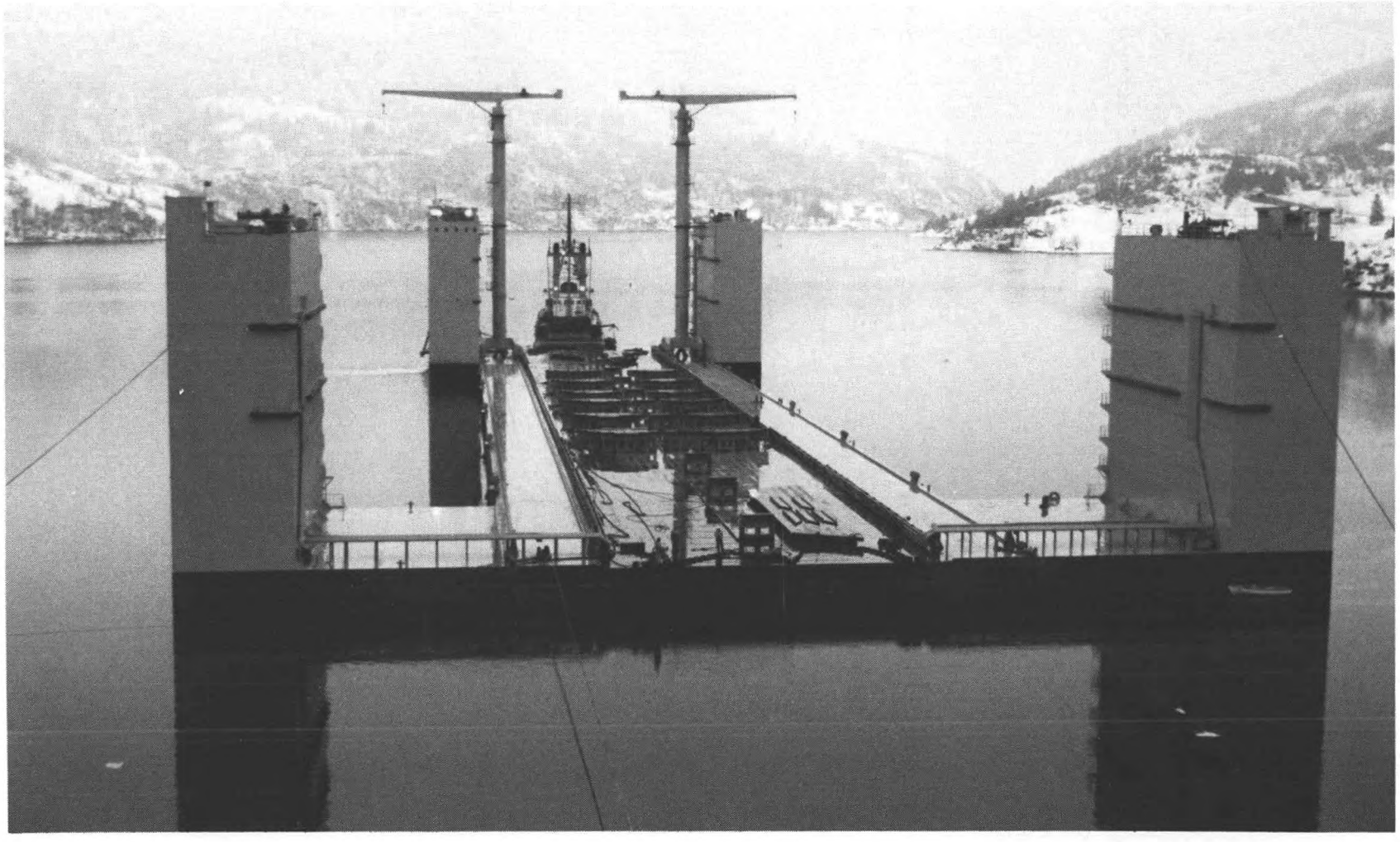
The data transmission system (arrowed, top left), with power unit below; the external antenna is arrowed, top right. The equipment automatically registers and transmits, via satellite, eight reports each hour, of temperature, pressure, wind direction and speed, position and time, for inclusion in the Global Telecommunication System.



General view of Ailsa Craig from the south; the balloon site is to the left of the picture
(See page 96.)

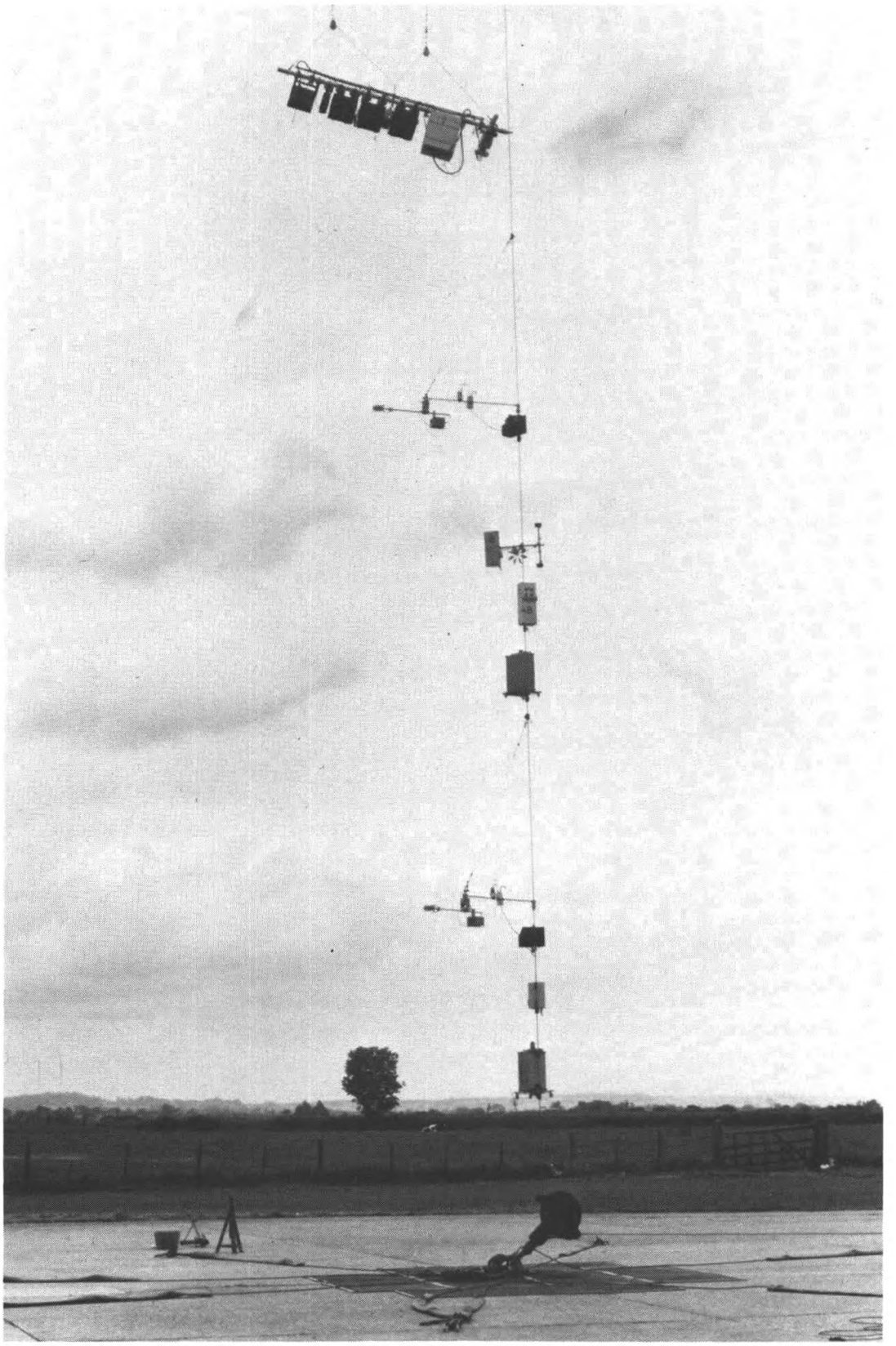


View of tethered balloon flying at about 250 feet
(See page 96.)



Photograph by courtesy of Ankerloekken Verft Foerde.

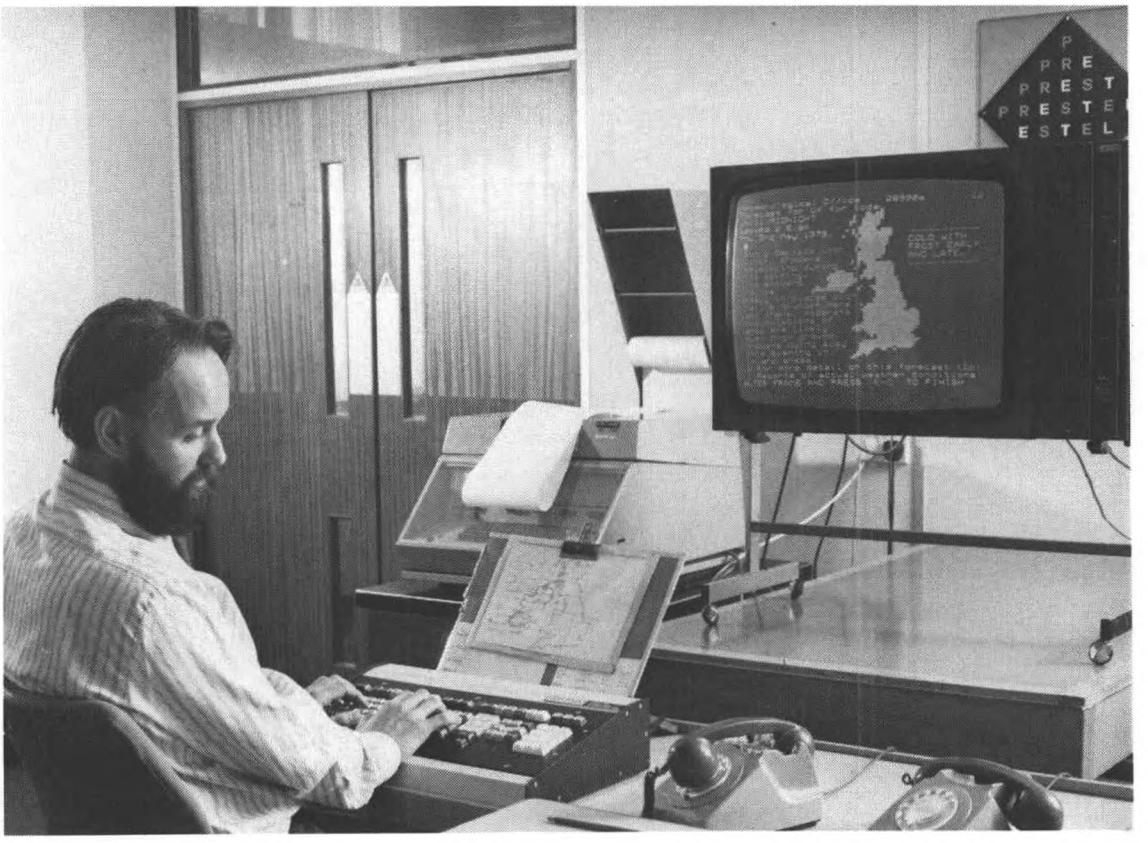
The tow of the trimdock *Ataka* from Norway to Egypt, over the period February to July, was one of the many marine operations for which the ship-routeing service provided weather forecasts.

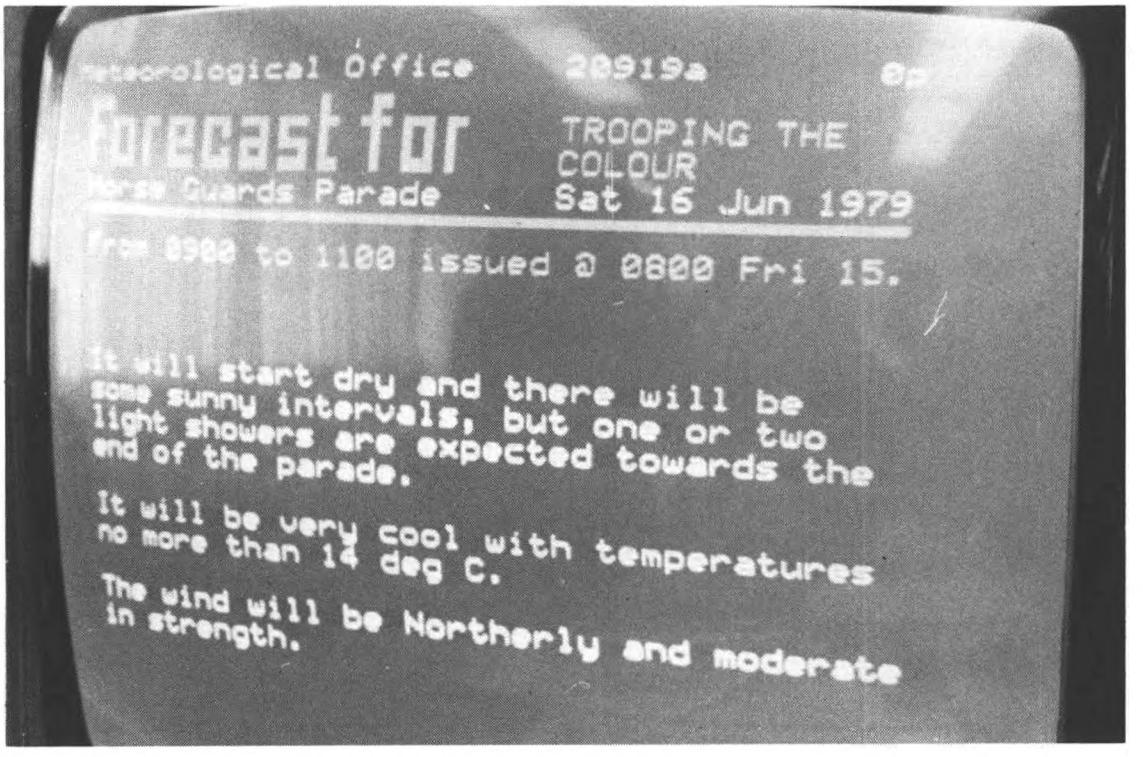


The balloon-borne instruments used in the fog and stratocumulus investigations at Cardington

The instruments shown are, from the top downwards: the droplet-sizing device, upper net radiometer, turbulence probe, radio transmitter, lower net radiometer, pressure sensor and second transmitter (see page 87).

PLATE VIII




forecast for
TROOPING THE COLOUR
Sat 16 Jun 1979
issued @ 0800 Fri 15.
It will start dry and there will be some sunny intervals, but one or two light showers are expected towards the end of the parade.
It will be very cool with temperatures no more than 14 deg C.
The wind will be Northerly and moderate in strength.

The Prestel editing terminal (upper) in the Central Forecasting Office, showing an example of the many types of weather information available

The special forecast (lower) was prepared for the visit of HRH Prince Charles on 15 June 1979.

TABLE XV — INSTRUMENT TESTING, CALIBRATION AND ACCEPTANCE

	Number of tests or calibrations
General meteorological instruments:	
Wind measuring	843
Pressure measuring	1030
Humidity measuring	76
Precipitation measuring	611
Radiation measuring	429
Sunshine recording	88
Temperature measuring	5945
Miscellaneous	10 689
Electrical/electronic instruments and systems	959
Electrical/electronic components	2607
Balloons	23 640
Radar reflectors	8200
Radiosonde parachutes	30 150
Radiosonde unwinders	2140
Mk 3 radiosonde component parts tested and accepted	174 486
Mk 3 radiosonde humidity transducers skinned and seasoned	7400
Mk 3 radiosonde pressure transducers calibrated	17 400
Mk 3 radiosonde pressure reference elements calibrated	17 550
Mk 3 radiosonde recoveries received	1274
Total	305 517

DIRECTORATE OF RESEARCH

SPECIAL TOPIC—STUDIES OF FOG AND STRATOCUMULUS

Introduction

The economic impact of fog has increased since the Second World War with the growth of air and road transport. The requirement to forecast surface temperatures for the power industry, in order to predict gas and electricity demand on a daily basis, is also linked to the fog and cloud forecasting problem.

In a wider context the study of layer clouds has a global significance because of their possible influence on the general circulation. The presence of extensive sheets of stratocumulus over the oceans affects the radiation budget of the boundary layer and also the transfer of heat, moisture and momentum across the boundary layer. This has led to increased interest in devising methods of incorporating layer clouds into general circulation models.

Our ability to forecast fog formation or dispersal has improved little since the 1940s for two main reasons: on the synoptic scale there is considerable uncertainty in forecasting cloud cover, particularly stratocumulus cloud; on the local scale there has been a lack of understanding of the factors which determine if and when fog forms at a given station, given a suitable synoptic situation. A study of the basic physics and meteorology of fog and layer cloud is necessary, therefore, to assess the prospects for forecasting on several different scales. It is also required for sensible comment to be made on the proliferation of suggestions for artificially dispersing fog and in understanding the interaction of cloud and radiation in general circulation studies.

Since the 1950s studies of fog and layer cloud had received scant attention until about a decade ago, when the rapid development of instrumentation and computer facilities attracted a renewed attack on this difficult field in several institutions, including the Meteorological Office. Work within the Meteorological Office started in 1971 in the Cloud Physics Branch with a study of the physics of the local factors determining the formation and dissipation of radiation fog. It was decided at the outset that numerical modelling work should run in parallel and interact with field observations. Studies were extended in 1975 to layer cloud.

This report presents the principal features and results obtained so far from these studies. They represent a relatively unexplored direction for cloud physics research and besides yielding significant insight into the physics of radiation fog and stratocumulus have also provided a useful framework for the study of several basic cloud physics processes, such as the effect of radiative transfer on droplet growth and the role of mixing.

Fog project: phase I

The first phase of the fog project began in 1971 with the initiation of a field project at Cardington, Bedfordshire. This was a collaborative venture between the Cloud Physics Branch, the Boundary Layer Branch's research group at Cardington and the Environmental Services Division, Atomic Energy Research Establishment, Harwell. Measurements of wind, temperature and humidity were made at several levels from the surface to 16 metres using an instrumented

mast. The visibility and the net radiative flux (the difference between the upward and downward radiative flux) were measured at four levels to 37 metres. The difference between the net flux at two heights gave the cooling or heating of the intervening layer due to the absorption of radiant energy. The surface energy balance was determined from measurements of the soil heat flux, the rate of moisture deposition on the ground and the surface net radiative flux. A few measurements of fog drop-size distributions, liquid water contents and aerosol characteristics were also obtained. Efforts to monitor the behaviour of the fog top were only partially successful; few data were available above the level of the instrumented mast.

In parallel with the development of the field project a numerical model of radiation fog was constructed. Although this was based on earlier work elsewhere, detailed observations allowed correction of some important misconceptions in earlier models, especially in their treatment of the water budget. The model consisted of equations describing the transfer of heat, water vapour and liquid water due to turbulent motions and also the transfer of long-wave radiation through the atmosphere. Turbulence was modelled using an exchange-coefficient formulation which assumed that turbulent transport occurs in the direction of and proportional to mean gradients. The important effect of the fog droplets on the radiation field was incorporated, as was the settling of droplets under the action of gravity. The model contained a realistic description of the surface energy balance, including the soil heat flux.

The combined results of the field project and the model have enabled the following picture of the formation and growth of radiation fog to be formed. On a clear night the ground cools by emitting long-wave radiation to space, mainly through the 8–13 μm atmospheric window. The heat loss at the surface is mainly balanced by heat conducted upwards through the soil as a result of the temperature gradient established within the first few centimetres. The turbulent flux of heat towards the surface makes only a small contribution to the surface heat budget because of the low level of turbulent mixing characteristic of a stable temperature profile. As the surface cools, the air within the first few metres radiates directly to the colder ground, producing radiative cooling rates of up to one degree Celsius per hour. Eventually the air at the surface becomes saturated and further cooling leads to dew deposition and hence a drying of the air. Whether or not fog forms depends upon the balance between radiative cooling, leading to saturation of the air, and turbulent diffusion, which although it can be cooling the air is also drying it. Both field observations and the model show that fog forms more readily with a low level of turbulent diffusion, associated in the field observations with very low wind speeds. As the fog increases in depth and liquid water content, radiative cooling due to the fog droplets, which radiate to space as did the ground initially, becomes dominant in the upper part of the fog. With increasing fog depth the radiational loss from the surface is reduced to a value below that of the soil heat flux. The surface temperature then starts to rise, leading to the lifting of the temperature inversion from the surface and the establishment of a superadiabatic lapse rate near the ground. The model suggests that eventually the inversion migrates towards the fog top although few measurements were available to confirm this from the first phase of the field project. Estimates of the water budget indicate that the liquid water contained within the fog at any instant comprises only a small fraction of the total water vapour condensed from the air up to that time.

The rest is condensed directly on to the ground as dew or deposited from the air by the settling of fog droplets.

Since the model was in good agreement with the observations it was used to examine some aspects of fog behaviour not amenable to measurement or which had not been observed during the field project. It was shown that the gravitational settling of fog droplets plays an important role in determining fog liquid water content. If settling is omitted from the model, liquid water contents become very large. The model suggests that the advection of a low-level cloud sheet can clear fog in an hour or two by cutting off radiative loss from the fog top and allowing the soil heat flux to disperse the fog. Solar radiation was introduced crudely into the model and this was found to be less effective at clearing fog, since long-wave radiative cooling continued from the fog top.

The results of the first phase of the fog project have led to a significant clarification of the constraints in the development of radiation fog. From a practical point of view it must be concluded that since fog formation depends on the small difference between the opposing effects of radiative cooling and turbulent diffusion it will always be difficult to forecast. However, given clear skies and a saturated atmosphere, the formation of radiation fog is imminent if the mean wind drops below 1 m s^{-1} since dew deposition will then cease, leading to direct condensation into the air. Once fog has formed, its further growth is controlled by the interplay of the many factors discussed above—summarized in Figure 1.

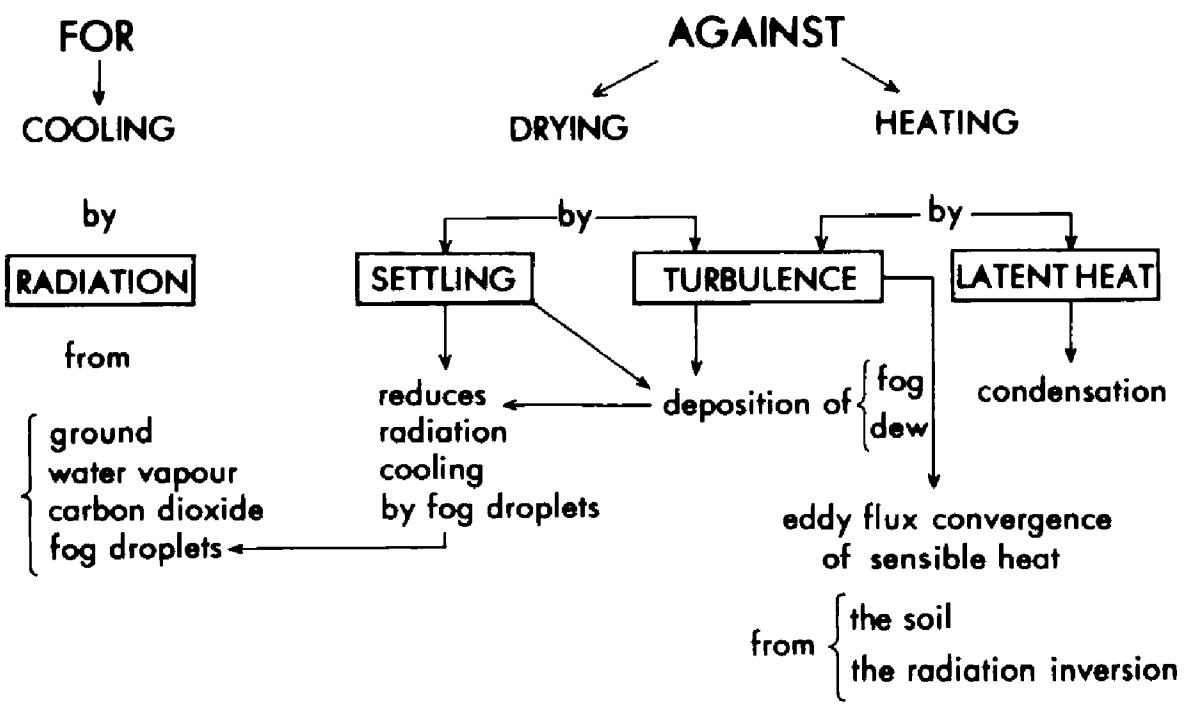


Figure 1—A summary of the factors involved in the formation and growth of radiation fog as elucidated by phase I of the fog project

Fog project: phase II

After the success of the initial project a second phase was planned to rectify the two principal deficiencies of phase I. These were firstly that the fog tended to grow well above the instrumented mast so that little information was obtained on the behaviour of the fog top, for example the factors which determined its

maximum height; secondly the use of tedious manual methods limited the quantity of microphysical data obtained. The sizes of the fog droplets were not calculated explicitly in the numerical model. This meant that an important practical property of the fog, namely the visibility, was not adequately calculated.

Instrumentation

Phase II involved a change from mast-based to tethered-balloon-borne observations during 1975/76, partly to monitor the behaviour of the fog top and partly to realize the potential of greatly extended microphysical observations made possible by the acquisition and modification of an 'Axially Scattering Spectrometer Probe' (ASSP). This device counts and sizes up to 2000 drops per second by measuring the amount of light scattered by individual drops drawn through a laser beam. The mean drop radius is determined with an accuracy of about 5 per cent but in contrast the drop concentrations are uncertain to within a factor of about two. Also mounted on the balloon cable were two net radiometers, a pressure sensor to monitor the height of the package and a Cardington Turbulence Probe. The latter measured fluctuations in temperature and wind from which the turbulent fluxes of heat and momentum could be calculated. A photograph of the instruments attached to the balloon cable is shown in Plate VII. The information from all the sensors was telemetered to the surface and recorded on magnetic tape. The drop-size data from the ASSP were displayed in real time in order to monitor the position of the fog top. This meant that the instrument package could be positioned as required with respect to the fog top.

Since the tethered balloon is based at Cardington, the same surface energy balance measurements were available as in phase I. However, by 1975 the Boundary Layer Branch had acquired an acoustic sounder, which is a relatively new device for investigating the atmospheric boundary layer. It works by emitting high-power pulses of sound and detecting the back-scattered echo. The scattering is produced by temperature inhomogeneities on the scale of the acoustic wavelength which are associated with such features as thermal plumes, and elevated and ground-based inversions. A time–height record of the inversion position is displayed on a chart recorder.

The Appleton Laboratory collaborated during phase II by running a ground-based, vertically-pointing 95 GHz microwave radiometer from which it was possible to infer the total liquid water path above the radiometer. This proved extremely useful in calibrating the liquid water content estimates produced by the ASSP.

Fog case-studies

During 1976–78 some interesting case-studies of fog were obtained with the new instrument package. These include a shallow and a deep fog dispersed by solar radiation, the steady growth of a deep fog, and a fog dispersed by increasing gradient wind.

Analysis of the data is still in progress but inspection has already yielded some interesting examples of fog behaviour. Within the body of a mature fog there is an almost wet adiabatic lapse rate produced by mixing generated by radiative cooling at the fog top and warming of the surface by the soil heat flux. The temperature inversion which was originally at the surface migrates to the fog top

and is coincident with it to within 10–20 metres. The acoustic sounder detects echoes from the base of the elevated inversion and hence identifies the position of the fog top. This has been confirmed by comparing the echo-layer height with the fog-top height given by the ASSP. The results of such a comparison for one fog are shown in Figure 2. The fog depth is an important parameter in forecasting the clearance of fog, especially by solar radiation. Since acoustic sounders are moderately cheap and quite robust instruments, they show great potential for aiding the forecasting of the clearance of fog, and operational trials of a commercial instrument are about to begin.

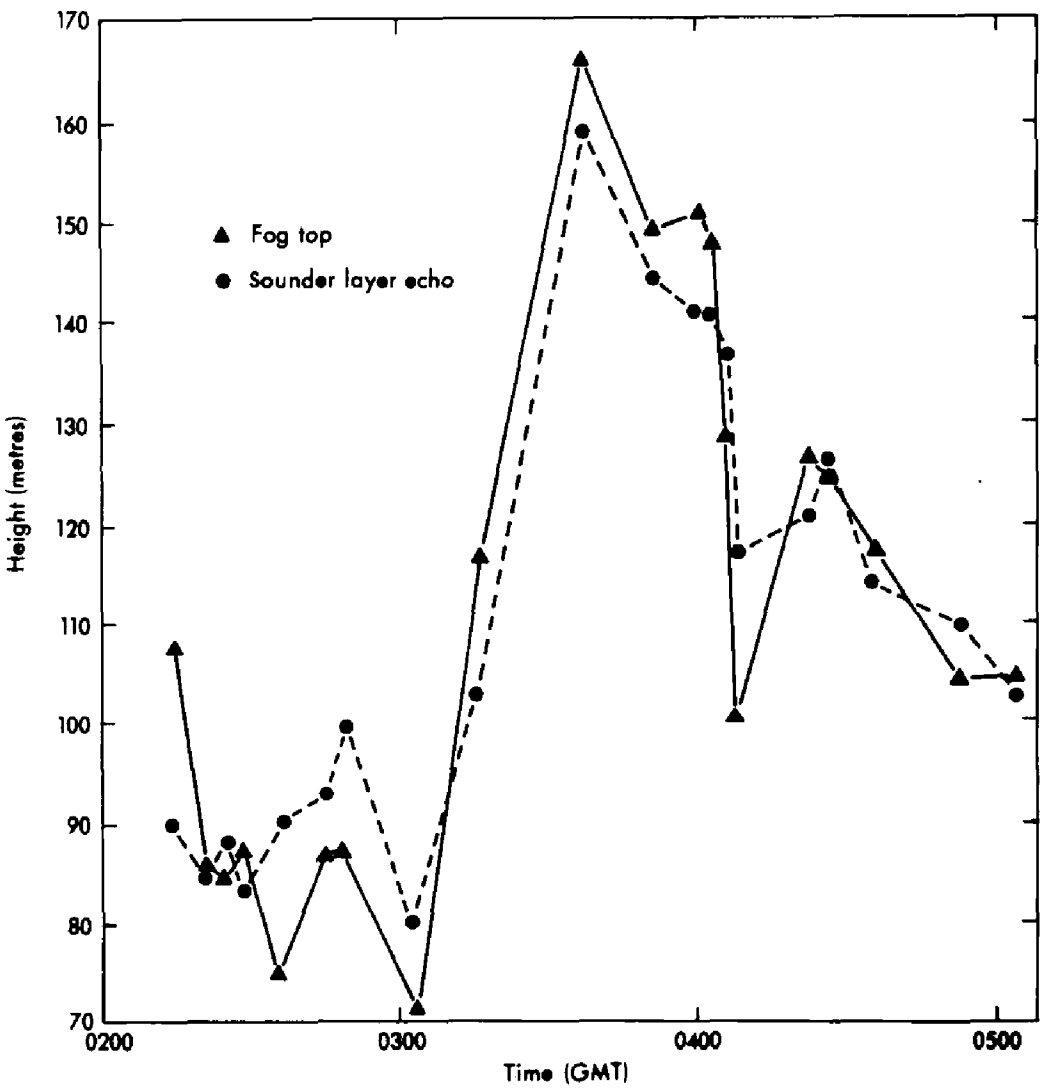


Figure 2—A comparison of the fog-top height given by the ASSP with the height of the acoustic sounder layer echo

The observations suggest that besides having a strong effect on the thermal structure of the boundary layer, fog also modifies the wind field, with the region of strongest wind shear migrating from the surface towards the fog top. This may enhance the mixing at the fog top. Certainly, the small drop sizes and constancy of liquid water content with height that are observed suggest strong mixing through the fog top. In contrast stratocumulus observations show relatively little mean wind shear through the cloud top and the liquid water content increases roughly linearly with height at about 75 per cent of the

adiabatic value. It should be noted that our observations are biased towards fog forming with a relatively large gradient wind. It is hoped that further analysis of the data will give fresh insights into the behaviour of radiation fogs especially concerning their growth and dissipation.

Fog modelling

In parallel with the gathering of greatly enhanced drop-size data using the ASSP, an explicit formulation of the growth of the fog droplets has been inserted into a model of fog which seeks to treat microphysical processes fully—the so-called 'microphysical model'. Several numerical experiments have been performed to determine the relative importance of factors governing the growth of the droplets and the resultant visibility. The behaviour of the visibility during the course of these integrations is quite realistic, the transition into thick fog being very abrupt. This behaviour compares well with the observations at Cardington and with previous fog studies. An example is shown in Figure 3.

Water normally condenses into the atmosphere on minute particles composed of hygroscopic material such as ammonium sulphate or sodium chloride. Such particles are known as cloud condensation nuclei (CCN). The microphysical model has been used to investigate the influence of the size distribution and concentration of CCN on the development of the drop-size distribution and visibility. These are found to be insensitive to the size distribution of CCN except that a very high concentration of large nuclei can slow down the development of a dense fog. In contrast they are sensitive to the concentration of CCN, a result anticipated from previous microphysical studies on cumulus clouds. As the CCN concentration is increased the mean drop size and minimum visibility are reduced, as shown in Figure 3. In fact the minimum visibility is found to be inversely proportional to the cube root of the nucleus concentration.

During the course of these studies it was realized that the net radiative loss from the drops fundamentally altered their growth rate. This has led to the modification of the classical droplet-growth equation by the addition of a term representing radiative heat exchange with the atmosphere. Whilst all other terms in the growth equation decrease with increasing drop size the radiative term increases, becoming roughly constant at 15 μm radius. Thus radiative exchange dominates the growth of the larger drops in fog and layer cloud. Furthermore it has been shown that when radiative loss from the drops is taken into account they can exist in equilibrium with a slight undersaturation of the air. This latter finding may have relevance outside the study of fog and stratocumulus. For example it might account for the persistence of sheets of cirrus cloud.

Initially the influence of radiative exchange on droplet growth was studied using a model fog with prescribed opacity and supersaturation. However, the development of the microphysical model provided an excellent opportunity to examine the importance of this effect within a fully interactive framework. It was found that with a low CCN concentration the radiative term had a significant effect, increasing the mean drop radius by 30 per cent. This enhanced the settling of the drops due to gravity and so by reducing the drop concentration increased the minimum visibility from 30 to 50 metres. With a very high CCN concentration the radiative loss term caused only a 5 per cent increase in the mean drop radius. This was because the fog was so optically thick that a drop only experienced a radiative loss over a short distance beneath the fog top. In

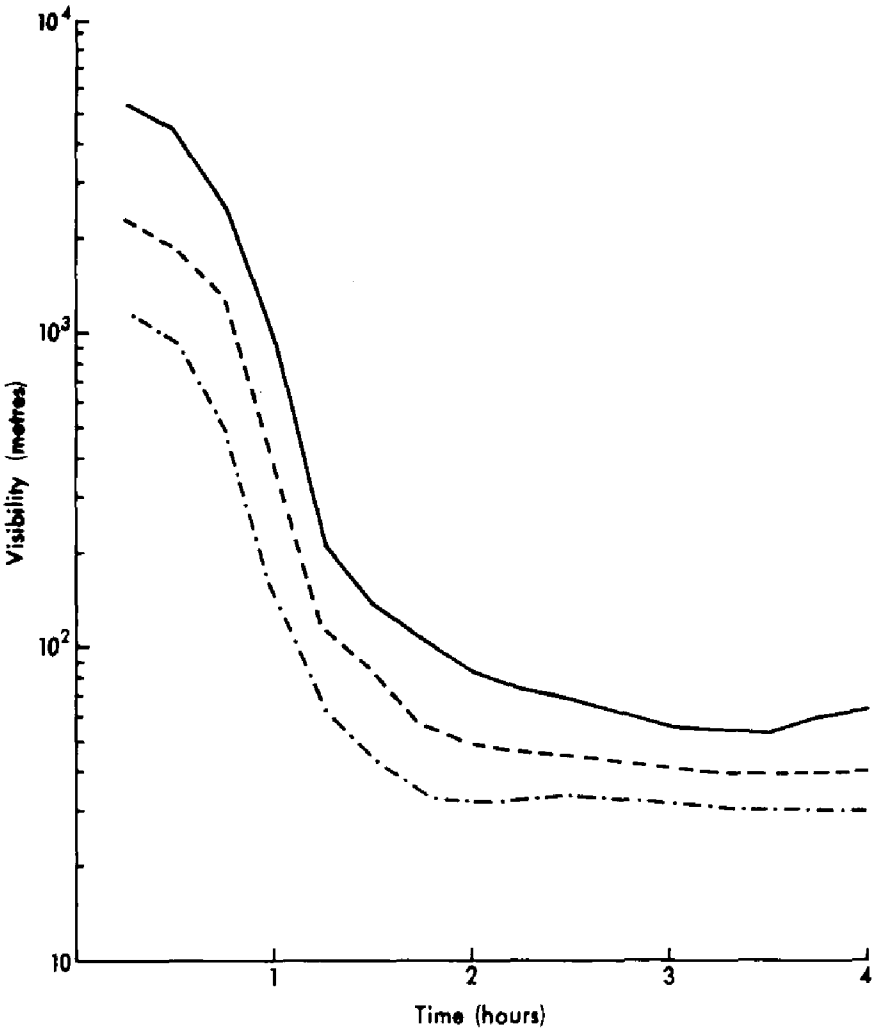


Figure 3—The visibility at 2 m from the microphysical fog model as a function of time

Each curve represents a different nucleus concentration at 0.03 per cent supersaturation:

——————— 170 nuclei per millilitre,
— — — — — 420 nuclei per millilitre, and
— · — · — 840 nuclei per millilitre.

summary it appears that radiative exchange between a drop and its environment has a significant impact on the development of the drop spectra in clean radiation fogs and maritime layer clouds and should be included in microphysical treatments of these topics.

It has been observed by other workers in the laboratory that by coating nuclei with long-chain fatty acids or alcohols their growth rate can be considerably reduced. This effect has been introduced into the model but with a growth rate reduction two orders of magnitude less than achieved in the laboratory, since it is not yet established that the carefully controlled conditions required to coat drops can occur naturally. Since the drops were growing more slowly, competition for available water was less and a much higher proportion of the nuclei grew into drops. In fact extremely low visibilities developed as a result of drop concentrations about three times as high as we have yet observed at Cardington. This strongly suggests that we have not encountered a situation in the field where the drops were significantly affected by a surface coating.

These results could have implications for one proposed method of inhibiting fog formation. It has been suggested that if the nuclei in the atmosphere could be coated as effectively as has been done in the laboratory, their growth rate would be reduced enough to prevent them from growing into fog drops on the time-scale of a night. However, it seems unlikely that it would, in practice, be possible to coat all atmospheric nuclei effectively and the model results show that imperfect coating may well produce a denser rather than a thinner fog.

Some of the Cardington observations show a combination of low mean droplet size and low concentration that cannot be reproduced in the model calculations. One possible explanation is that the turbulent mixing in a mature fog is greater than that implied by the exchange coefficients used in the model. These were constant in time and appropriate to a stable temperature profile. However, the lapse rate within a mature fog was found to be close to that of the wet adiabatic, which would indicate turbulent mixing (and hence exchange coefficient values) considerably greater than that assumed in the model. As a step towards examining this problem the original model (excluding explicit microphysics) has been extended to include the solution of the momentum equations in one dimension with the exchange coefficient functions of wind shear and stability. Initial results from the extended model confirm that the region of maximum wind shear moves towards the fog top in a mature fog. It is envisaged that the extended model will prove a useful aid in the interpretation of the field observations.

Stratocumulus case studies

The instrument package used during phase II of the fog project has been designed to yield useful information in layer cloud as well as in fog. The tethered balloon could operate to a height of 1.5 km. Studies of stratocumulus commenced during 1976 and detailed measurements have been obtained at night in three cloud sheets which ranged in depth from 175 metres to 750 metres. The outstanding characteristic of tethered-balloon observations is the high degree of vertical resolution obtainable compared to aircraft measurements. However, the data are confined to one location, unlike those from an aircraft. Initially nocturnal stratocumulus has been studied in order to be able to omit the added complexity of solar radiation. The behaviour of nocturnal stratocumulus is an important problem affecting the forecasting of fog and night-minimum temperatures.

All three cloud sheets were found to have a similar temperature and humidity structure, with a dry-adiabatic lapse rate below cloud changing to a wet-adiabatic lapse rate within the cloud. In the case of the two thinnest clouds the adiabatic lapse rate changed to a stable lapse rate close to the ground. In contrast to the well-mixed temperature profiles the humidity-mixing ratio decreased from the ground to the cloud top in all three cases. Immediately above the cloud top the temperature increased abruptly, typically by 5 °C in a distance of less than ten metres. Within the accuracy of our measurements ($\approx$ 2 metres) the cloud top was located at the base of this sharp inversion. There was also a sharp decrease in humidity-mixing ratio immediately above the cloud top but this was less well-defined than the temperature step. The humidity-mixing ratio reached a minimum a few tens of metres above the cloud and then slowly increased again above this. This feature has been observed from aircraft measurements and as yet no tenable physical explanation is available.

In all three clouds the liquid water content increased roughly linearly with height at approximately three-quarters the adiabatic rate. The reduction below adiabatic liquid water content values is due to the mixing-in of dry air from above the cloud. The drop concentration fluctuated by up to 50 per cent but showed no mean trend with height. In contrast the mean radius increased regularly with height and showed remarkably few fluctuations. This observation is in qualitative agreement with the theory of inhomogeneous mixing advanced recently by workers at the University of Manchester Institute of Science and Technology. According to this, dry air is mixed into the cloud in discrete parcels and evaporation of the drops surrounding the parcel takes place on a much shorter time-scale than diffusion of the reduced humidity through the cloud. This leads to some regions where all the drops have evaporated and others where they are unaffected, hence the constant mean radius and fluctuating concentration. In contrast if the reduced humidity due to mixing-in of the drier air were evenly distributed through the cloud before the drops could react, i.e. homogeneous mixing, then only partial evaporation of the drops would occur, leading to fluctuations in drop concentration and mean radius which were correlated.

The observed variations of net radiative flux through the clouds were in good agreement with theoretical predictions. The latter were made with a computer model of radiative transfer which allowed the incorporation of observed cloud microphysics data. Radiative cooling rates of up to ten degrees Celsius per hour were observed in the upper part of the cloud. This drives the turbulent mixing within the cloud and in the sub-cloud layer. The turbulence probe data within the cloud showed that the turbulent motion had cold downdraughts and warm updraughts of approximately the same intensity. This is in contrast to the behaviour of convection near the ground on a sunny day where the cold downdraughts are of a much smaller intensity than the warm updraughts. The air above the sharp inversion at cloud top was essentially non-turbulent. The dominant scale of turbulent mixing decreased from the cloud base towards the cloud top owing to the restricting influence of the inversion.

At the cloud top the dry warm inversion air is believed to be drawn into the cloud top by entrainment. This occurs when a non-turbulent fluid overlies a turbulent one. Parcels of non-turbulent air are enfolded into the turbulent air. The turbulence probe data suggest that turbulent entrainment at the cloud top occurs mainly by intermittent breakdown of the sharp capping inversion through Kelvin–Helmholtz instability (a turbulent instability generated by wind shear) with entrainment occurring on a scale of about ten metres.

One of the stratocumulus layers persisted in local equilibrium for at least five hours. That is to say the temperature above, below and within the cloud remained virtually constant over this period as did the cloud-top height and cloud depth. Only the surface dew-point decreased slightly. Furthermore as far as could be ascertained from routine sonde ascents the cloud-top height did not vary significantly for several hundred kilometres upstream and downstream of Cardington. The energy and water budgets of this cloud base have been the subject of detailed investigation since they are key elements in the maintenance or dispersal of the cloud.

Above the sharp temperature step at the cloud top there was no turbulent transfer, and advection and the local rate of change of temperature were negligible. The energy balance here was between subsidence heating and

radiative cooling to the colder cloud top. Since the latter has been measured it proved possible to estimate the velocity at which the air was subsiding. An examination of the synoptic-scale wind field suggested that the divergence was concentrated in the surface stable layer, implying that subsidence continued unabated down to this layer. Since the cloud-top height was constant it was possible to equate the rate of growth upward of the cloud due to entrainment (the entrainment velocity) to the subsidence velocity and hence to calculate the contribution of entrainment to the heat and water budget of the cloud-capped boundary layer.

The budget study of the boundary layer beneath the cloud top was completed by measurements of the surface energy budget and of the net radiative loss from the cloud top. At the surface the net radiative loss and the soil heat flux were small. The downward-directed sensible heat flux appeared to be used for evaporation since the upward-directed latent heat flux was of a similar magnitude. The large radiative loss from the cloud top was not balanced by the small residual energy flux from the surface, nor by the contributions due to entrainment and vertical advection due to subsidence. Thus, by elimination, horizontal advection must be mainly responsible for balancing the radiative loss even though horizontal gradients were weak. The accuracy of synoptic data is insufficient to allow the reliable identification of such gradients from synoptic observations.

Although the importance of advection in the heat balance of nocturnal stratocumulus over land has been demonstrated for only one case it is probably always important since under stratocumulus the surface fluxes will be smaller than the cloud-top loss. It may not always be true over the sea, where surface fluxes can be of the same magnitude as radiative loss, or for the daytime convective case where they may be larger.

In contrast to the heat budget no individual terms dominated the water budget. The evaporative loss from the surface was evidently not quite sufficient to saturate the dry entrained air and keep it saturated while subsiding through the cloud layer, as demonstrated by an extended clearance a hundred kilometres downstream of Cardington.

Future work

These studies have yielded new insights into the behaviour of radiation fog but so far have tended to establish why fog forecasting is difficult rather than suggest new forecasting methods. It is too early to decide if further experimental work on fog is worth while since the latest experimental results are not yet fully analysed. The extended model may turn out to be of value in forecasting. However, our ability to forecast fog occurrence or depth may be restricted by the accuracy with which we can determine a representative humidity profile, this being more variable than the temperature profile. The use of acoustic radar to give real-time measurements of fog-top height may lead to more accurate forecasts of the dispersal time of fog.

The study of stratocumulus is far from complete but so far it has led to the suggestion that the supply of moisture from the ground may control the maintenance of nocturnal stratocumulus over land. It has also been demonstrated that some aspects of stratocumulus are essentially multidimensional phenomena whereas the behaviour of radiation fog may be fairly well understood using a one-dimensional approach (although forecasting

radiation fog may be a two-dimensional problem involving the advection of moisture). It is clear therefore that future measurements of the energy budget of stratocumulus must be two-dimensional and hence will involve the use of an aircraft, in our case the Meteorological Research Flight's Hercules. The instrumentation mounted on the Hercules was described in the *Annual Report 1977*. Initially, two-dimensional measurements over the sea will be made during daylight hours, the logistics of night-time flying being rather complex. Therefore we must contend with solar absorption within the cloud and separate measurements of this are planned. Looking further ahead, to investigate the modification of stratocumulus due to passage from sea to land a joint tethered-balloon and aircraft program may be desirable.

Turbulence probes flown at several levels on the tethered-balloon cable may be used to elucidate the turbulence structure of the cloud-capped boundary layer in more detail than has hitherto been possible, especially in respect of the larger scales of motion. They may also provide more information on the connection between the turbulence structure of the surface shear layer and that of the upper convective layer. The results from the steady-state case-study suggest that it is worth while to undertake a synoptic study of the behaviour of stratocumulus in terms of surface budgets and subsidence rate.

As yet we have not felt it necessary to construct a detailed numerical stratocumulus model since there are already in existance elsewhere several sophisticated analytical and numerical models. Preliminary attempts have been made to model stratocumulus microphysics by consideration of a collection of nuclei in a closed parcel undergoing a slow prescribed ascent. This has proved surprisingly successful in simulating observed droplet spectra and indicates some dependence of the droplet spectra on the initial nucleus spectrum. Future progress in modelling the microphysics of stratocumulus is likely to involve the use of Monte Carlo techniques to represent the random motion of the parcel. Further consideration will be given to formulating a realistic, interactive macrophysical model of stratocumulus which is still simple enough to allow repeated integrations in order to determine its sensitivity to various boundary conditions. Within such a model special attention will have to be given to the interaction between the subsidence rate and the structure of the inversion, which will require a high degree of resolution at the cloud top.

OTHER WORK OF THE DIRECTORATE OF RESEARCH

PHYSICAL RESEARCH

Cloud physics

Many of the physical and some of the chemical properties of the atmosphere are profoundly affected by the various forms of water substance it contains. The creation of precipitation has an obvious importance but the energetic and other influences of phase changes of water, on the transmission of various forms of electromagnetic radiation for example, are significant also. Some of the ramifications of these latter effects are highlighted in the Special Topic which describes the rationale for and results of recent studies of fog and stratocumulus cloud.

As a result of laboratory studies of water drops and ice crystals the fundamental physics of many processes thought to be important in cloud formation and evolution are understood, in outline at least. Much of present-day cloud physics research is concerned with the application of that understanding to the atmosphere. Such research requires substantial efforts to observe the dynamics and structure of naturally occurring cloud and precipitation and to interpret, model, and thereby understand, the results of the observations.

For some years a system for studying the large-scale structure and dynamics of cloud systems by means of 'dropsondes' released from aircraft has been under development. The C-130 Hercules aircraft of the Meteorological Research Flight has been equipped to release these sondes and track them as they fall by parachute and so provide measurements of the wind. Sensors on the sonde telemeter data on temperature, humidity and pressure back to the aircraft, which can deal with up to 5 sondes in the air at any one time. In 1979 the system was used for the first time to study warm-front structure over the North Atlantic. Although this was only partially successful owing to some failures in the sondes, attempts to understand and interpret the results obtained are under way. Further studies are planned in 1980.

The spatial distribution of air motion and the growth of cloud and precipitation in vigorous cumulus clouds have been observed from the C-130 aircraft. Attempts to simulate this development with a 3-dimensional numerical model have been successful in a small number of case studies. A particularly pleasing feature has been the prediction of the growth of new convective cells in positions corresponding to those observed in the atmosphere. First attempts to incorporate electrification processes into such a 3-dimensional model have been completed. The work has identified a number of sensitive parameters and provides some interesting predictions to be tested against observations.

On the smaller scale, in addition to the studies of fog and stratocumulus, significant efforts have been made to instrument and use the C-130 aircraft for studies of the microstructure of a range of cloud types. As a result the aircraft now has instruments for detecting, counting and sizing, with varying degrees of accuracy, particles ranging from the nuclei on which cloud droplets form to the largest raindrops and snowflakes. Particularly noteworthy developments during the year have been the installation of a device to produce holograms and another to produce 2-dimensional shadow images of cloud and precipitation particles. These instruments have been used in a number of experiments to explore the

relationships between particle size and position, temperature and air velocities within cloud. Attempts to model the relevant processes have had some success in matching observation with prediction. The importance of obtaining concomitant microphysical and dynamical data has been emphasized.

The extensive amounts of data obtained in such experiments are beginning to provide useful statistical data for civil and military aviation. The distribution of liquid water content and droplet-size distributions in non-precipitating cloud have received attention during the year. This work, which attempts to provide basic data for helicopter icing studies, will continue and be extended to include precipitating cloud in the future.

The atmospheric boundary layer

The boundary layer—roughly speaking the lowest kilometre of the atmosphere—is important not only because it provides the immediate environment for many human activities, but also because it achieves the transfer of heat, momentum and moisture between the earth's surface and the atmosphere above. Its study covers a large field so inevitably effort has been concentrated on selected topics, notably the effect of topography on the atmospheric boundary layer. This remains an area of great ignorance despite its relevance to local weather, the spread of pollutants and parametrization in large-scale numerical models of the atmosphere.

During the past year a 3-dimensional numerical model has been used to investigate stably stratified flow over a hill, paying special attention to the boundary conditions in the regions of inflow and outflow of the computational volume. Of particular interest is the way the forces on the surface vary with stability. Initial results show that changes in these are mainly associated with the transition from a flow which generates lee waves to one in which the fluid remains in nearly horizontal planes as it passes the obstacle. The latter becomes more prevalent as stability increases.

Concurrent with this numerical work has been the analysis of the data obtained during the Ailsa Craig experiment which took place in autumn 1978. Ailsa Craig is a fairly isolated, nearly hemispherical island lying off the coast of Ayrshire (see Plate V). Flow characteristics were recorded with the aid of anemometers on masts, balloon-borne turbulence probes and the C-130 aircraft of the Meteorological Research Flight. During the experiment mean velocities were measured in a turbulent flow well separated from the surface—the first time this has been achieved. Several interesting and unexpected features have emerged, notably the presence of upward motion immediately downstream of the island—indicating that air flowing over the summit does not come down to the surface again in this region, contrary to previous ideas. The aircraft measurements have shown that there were powerful vortices downstream of the island, with vertical velocities comparable with horizontal flow speeds. Such motions have important implications for momentum transfer as well as constituting a hazard to aviation. The results will be assessed in the light of earlier numerical simulations.

Turbulent flow over long ridges is also being studied, using both numerical and analytical techniques. In support of this theoretical work an experimental study of flow over ridges and valleys in South Wales has been planned for 1980;

the regularity of the hill and valley structure there will simplify the interpretation of results. Both mast and balloon-borne equipment will be used, trials having confirmed the feasibility of the latter.

Over more homogeneous terrain large rolls are often observed, with length much greater than their diameter. These have been simulated by a numerical model, in which the effects of small-scale eddies and buoyancy are included. The results show several interesting features such as the production of countergradient fluxes by the large eddies and the generation of gravity waves which radiate energy upwards through the overlying stable layer. A maximum transfer of momentum across the boundary layer was obtained with the rolls orientated slightly to the left (looking downwind) of the geostrophic wind. This accords with experimental observations. Plans are in hand to extend this work to include water vapour and condensation and additionally to model the stable boundary layer.

Another major topic is the role of the atmosphere in transporting and dispersing polluting materials. In previous years considerable emphasis has been placed on the role that vertical dispersion plays in determining the concentration field downwind of a source, and on the nature and magnitude of the various 'sink' mechanisms. For some pollutants, especially potentially hazardous ones, the most important questions are whether or not the plume will pass over a specified point or area, and if it does what the time-averaged concentration will be. These considerations have led to a study of plume width and plume swinging, the latter in response to eddies whose scale is larger than that of the plume (including the effect of synoptic features such as depressions and anticyclones). Bodies of data have been analysed and useful results on the statistical nature of lateral spread have been obtained. The one area where progress has been slight is in the effect of mesoscale eddies, that is wind fluctuations on the scale of ten to several hundred kilometres. These are very dependent on topographic features and hence are difficult to quantify with the synoptic network of observing sites.

It is important to know how accurate predictions of the concentration of pollutants are likely to be, and studies have been made of likely sources of error. In particular, estimates have been made of the errors caused by imperfect knowledge or prediction of the wind field, and a comparison has been made of observed and predicted concentrations downwind of a large power station. Quite large discrepancies between prediction and observation can occur in some conditions.

Accepting these limitations, it is important that when a hazardous chemical is accidentally released into the atmosphere, the authorities dealing with the emergency receive guidance on the likely travel and spread of the material as soon as possible. A scheme has therefore been devised whereby forecasts can be obtained rapidly from wind speed, wind direction and Pasquill stability category supplied by a local meteorological office. The spread of material downwind is estimated by using transparent overlays of typical plumes, which can be placed on the appropriate Ordnance Survey map.

The importance of vertical dispersion has not been neglected. Important progress has been made in placing Pasquill's universally used scheme for categorizing vertical plume-spread in terms of meteorological parameters on a much sounder scientific footing. His categorization parameter P (which originally took one of seven values labelled A to G, but was later given a continuous numerical scale) has been related to the non-dimensional Kazanski–Monin stability

parameter μ. This parameter depends on the two surface fluxes of momentum and heat which drive the micrometeorological turbulence field. Tentative relations between P and μ have been derived for both unstable and stable conditions.

The vertical dispersion of non-buoyant particles in a neutral boundary layer has been studied using a random-walk technique. The results agree well with those derived from similarity theory. Recently the model has been extended to include the effects of deposition and the settling velocity of the particles (if any). Diffusion in stable and convective boundary layers will also be studied.

In support of all this work, plans are in hand to refurbish the experimental equipment, notably the Cardington balloon-borne sensors. These will be replaced with lighter and more refined sensors, together with better telemetry and recording systems.

JASIN

The JASIN (Joint Air–Sea Interaction) project is a field experiment to study the interaction of the atmospheric and oceanic boundary layers. Proposed some ten years ago by the Royal Society and the Royal Meteorological Society and later involving other agencies including the Institute of Oceanographic Sciences, it finally reached its climax with a two-month phase of intensive observations in the vicinity of Rockall, from ships and aircraft of several nations, during the summer of 1978. The Office's contribution to JASIN came from both the Boundary Layer Branch and the Meteorological Research Flight.

Since the end of the experimental phase of the project, the past year has seen considerable effort devoted to data reduction. The Porton-based team of the boundary layer group have been responsible for handling the surface data from one of the buoys and the three British ships that participated in the meteorological program. These data have now been processed and tapes supplied to co-operating scientists including those at the Jet Propulsion Laboratory, California, who are concerned with evaluating data from the SEASAT satellite. The Porton group is also about half-way through the processing of the 200 hours of data obtained from their turbulence probe mounted on the tethering cable of the kite balloon flown from HMS *Hecla*. The processing of the data from the extensive radiosonde program carried out by them during JASIN is also well advanced.

Data from the Meteorological Research Flight's C-130 aircraft are also being processed. An important aspect is the intercomparison of these data with those obtained from other aircraft (from the United States of America and the Federal Republic of Germany) taking part in the experiment, and this is proceeding satisfactorily.

Meteorological Research Flight

The Meteorological Research Flight (MRF) of the Meteorological Office is located at the Royal Aircraft Establishment (RAE) Farnborough. It comprises two RAF aircraft, a Hercules C-130 and a Canberra PR3 suitably and extensively instrumented to carry out research from near the sea surface (with the Hercules) to the lower stratosphere (with the Canberra). The flight-deck crews are provided by the Royal Air Force. As the preceding sections record, the MRF

is used as a research facility by several research branches inside the Meteorological Office and by universities and other research groups outside the Office, but studies of some atmospheric phenomena are also carried out by scientists based at Farnborough as part of the staff of the Flight.

The major part of the research effort within MRF has been concentrated this year on gathering and analysing data from the boundary layer over the sea. Analysis of data obtained outside the JASIN context has shown excellent agreement of the aircraft results with previous measurements and for the first time has clearly shown substantial differences in turbulence structure between measurements made along-wind and across-wind. The measurements have also demonstrated the importance of density variations due to humidity in producing and maintaining the turbulent fluxes. This is especially true over tropical oceans where the humidity is generally much higher.

Recent flights have been made in conjunction with an HS125 aircraft from RAE Bedford which is specially instrumented to measure wind velocity fluctuations up to 300 Hz. This will not only allow comparisons to be made between different instrument systems at high frequencies, but is also designed to explore the small-scale structure of atmospheric turbulence.

The Canberra PR3 aircraft continues its routine monitoring of the lower stratosphere to determine the water vapour content and its variation with latitude and time. As well as this, however, the aircraft possesses multichannel radiometers, designed and constructed by the Department of Atmospheric Physics, Clarendon Laboratory, Oxford, which are similar to those flown on some of the NIMBUS satellites, and there have been collaborative projects between Oxford and MRF. At present some of the original filters have been replaced to allow measurements to be made within the 1–2 μm band, and several flights have been made to measure the radiation from and through various types of layered cloud.

The co-operative project between the Office and the Central Electricity Research Laboratories (CERL) aimed at studying the fate of sulphur dioxide emitted into the atmosphere by power stations, continues. Cloud-water, rain-water, air and particulate samples will be collected on the C-130 aircraft for laboratory analysis whilst the concentrations of sulphur dioxide, oxides of nitrogen and ozone and the acidity of cloud- and rain-water will be measured during flight. To facilitate tracking of the relevant power-station plume, CERL are developing instruments to detect tracer compounds which will be injected into the plume at source. Manufacture and modification of instruments to be mounted on the aircraft are being carried out by CERL whilst the MRF with RAE backing are responsible for their installation on the aircraft. It is planned to have the aircraft fully operational for the experiments by early 1980.

Atmospheric chemistry

The long-term monitoring of the chemical content of rain-water was continued at three stations, Lerwick, Eskdalemuir and Bracknell, with automatically opening and closing rain-gauges. The chemical analysis of monthly catches is performed by the Laboratory of the Government Chemist. A 3-channel gas chromatograph has been operated on the MRF C-130 aircraft, notably on five flights during a detachment to Dakar in September. Over 170 chromatographs were taken, and 27 bottle samples were brought back to Bracknell for laboratory analysis. Study of the data is in progress. There are some indications that in

these initial flights, contamination, which is a particularly severe problem with trace-species measurement, may hamper the assessment of the effectiveness of Saharan dust plumes as a sink for chlorocarbon molecules. The existence of such a sink, if proven, could cause substantial reductions in the calculated losses of stratospheric ozone arising from the photodissociation of these molecules. The gas chromatograph can also measure nitrous oxide and carbon dioxide, and after minor modifications a flying program to investigate the distribution of sources and sinks of all these molecules is planned.

Numerical computer calculations with a radiative–photochemical model of the effects of chlorocarbons, carbon dioxide and nitrous oxide upon the stratospheric ozone layer have been made. They indicate that the expected increase in carbon dioxide will lower the temperature in the stratosphere and that this will tend to increase the ozone, offsetting to some extent the decrease in ozone that is expected to occur as a result of continued emission of chlorofluorocarbons (CFCs) into the atmosphere.

Calculations using fields of ozone, water vapour and NO_x from a general circulation model have yielded global distributions of OH, a species of great importance for both stratospheric and tropospheric chemistry. The results demonstrate the influence of asymmetries in circulation (due to geographic features) on global distributions of chemical species and show that it is often unsafe to take simple global or zonal averages in model calculations.

Results from our studies of the effects of chlorofluorocarbons on ozone made with a 2-dimensional hemispherical numerical model were published in a major report issued by the Department of the Environment. The experiments reported there have since been extended in two noteworthy respects. Firstly, a six-column global model produced results in fair agreement with the latest results of the three-column hemispheric model. The indicated equilibrium ozone reductions appropriate to the late 21st century were 11 per cent for the hemispheric model and 14 per cent for the global model assuming a steady state input release of CFCs at the 1975 rate. It thus appears that the earlier calculations were not severely affected by the presence of an equatorial boundary. Secondly, a version of the hemispheric model using values of the dissociation coefficients averaged over the diurnal cycle produced an equilibrium ozone reduction of only 8 per cent, thus indicating the consequences of adopting this frequently used modelling simplification.

High atmosphere and satellite meteorology

The infra-red radiometer, known as the Stratospheric Sounding Unit (SSU), which was launched aboard the US polar-orbiting operational meteorological satellite TIROS-N in October 1978, has continued to provide data. A second instrument was launched aboard NOAA-6 in June 1979. This instrument is functioning perfectly. Observations from these instruments now form part of the input to the scheme, operated by the National Oceanic and Atmospheric Administration (NOAA) in Washington, for deriving mean temperatures for various layers between 1000 and 0.4 mb. These temperature measurements are distributed world-wide and contribute to the observational base for numerical forecasting at various meteorological centres, including Bracknell.

Data from the SSUs and some of the data from the other temperature-sounding instruments are being received at Bracknell and processed daily to produce analyses of geopotential for surfaces between 100 and 1 mb. The quality of

these stratospheric analyses has been assessed against hand-drawn charts based on radiosonde and rocketsonde observations. The accuracy of the satellite products is generally acceptable, although further work is required to improve the quality, particularly in areas affected by stratospheric warmings. The satellite-based analyses are being used for studies of the dynamical behaviour of the stratosphere. Analyses are being distributed, to various research users in the United Kingdom and abroad, as books of charts, facsimile documents, telex messages and on magnetic tape.

Six more SSUs will be launched over the next 5 years and work on them has continued during the year. Laboratory work has continued to improve understanding of the instruments in orbit.

There has been close contact with the European Space Agency on many aspects of the operation of the European geostationary satellite, Meteosat. The Office has continued to assist in the evaluation of various Meteosat quantitative products as the techniques to derive them are developed. Checks on the winds, derived from observations of cloud motion, suggest that these are now at least as good as those derived from other geostationary satellites. Analysis of radiation, temperature and humidity profiles, measured by the Meteorological Research Flight C-130 aircraft during flights over the Atlantic in 1978, was completed. This provided valuable checks on the theoretical models used to compute atmospheric transmission at wavelengths around 11 μm as well as radiometric calibrations for the Meteosat sensors. A further set of measurements, in conditions of high temperature and humidity, was made during flights from Dakar in September. These observations are being analysed.

Techniques have been developed for handling raw data, received at Lasham, Hants, from temperature sounding instruments on TIROS-N and NOAA-6. Various schemes for retrieving temperature profiles for the troposphere are being tested. Studies of the technique for deducing surface winds over the ocean from measurements of microwave back-scatter have been hampered by delays in receipt of observations from the relevant instruments on SEASAT.

Firings of Skua meteorological rockets have been made at South Uist (Hebrides) to coincide with some of the overpasses of TIROS-N and NOAA-6. Direct comparison of the radiances observed by the SSUs on these spacecraft with detailed temperature structure obtained by the rocketsonde are extremely valuable for checking the performance and long-term stability of the satellite instrumentation. Two rocketsondes were flown on 2 October in conjunction with an experiment to study the diurnal variation of ozone in the 40–70 km region. This experiment involved measurements of the atmospheric attenuation of ultra-violet sunlight and moonlight. The Petrel rocket systems and ultra-violet sensors worked well and excellent sets of observations were obtained from all four flights. Satisfactory progress is being made in the analysis of data from a single night-time flight made in September 1978.

Routine observations of total ozone have been maintained at Bracknell, Lerwick, Mahé (Seychelles) and St Helena. The instrument at Lerwick was adjusted and recalibrated by comparison with one of the Bracknell instruments. A spare instrument was installed at Singapore in January, to improve the observational coverage in that region. Observations are being made by staff of the Singapore Meteorological Service.

An instrument to measure nitrogen dioxide, by detecting the associated attenuation of sunlight at wavelengths around 440 nm, is now working. Several

sets of observations have been collected and tests are being made to check the stability of the equipment and the method of interpreting the observations.

The program of monitoring back-scatter from aerosol in the stratosphere, using a dye-laser, was terminated. Cloudiness made it impossible to obtain a useful number of observations with the existing equipment. During the first half of the year, the National Physical Laboratory flew the low-resolution water vapour radiometer, which is being developed in conjunction with the Office, on several large balloon payloads in North America. These flights provided observations up to about 30 km but also revealed a need for improvements to the in-flight calibration system. A modified system was successfully demonstrated during a flight organized by the Office.

The Short Period Weather Forecasting Pilot Project

The ability to observe and analyse cloud and precipitation patterns has been greatly improved by advances in radar and satellite imagery and by new methods of processing, transmitting and displaying the data. These improvements hold considerable promise for improving the accuracy and detail in local forecasts of precipitation for periods of 0 to 6 hours ahead and in some cases up to 12 hours ahead. The Short Period Weather Forecasting Pilot Project is a 5–8 year program to develop these techniques and to optimize their impact on the forecasting capability of the Meteorological Office. The project will be a balanced program of fundamental and applied research with the new data sources leading both to an improved understanding of the detailed structure, mechanism and evolution of precipitation systems, and to the development of improved forecasting techniques. Before these tasks can get under way, however, it is necessary to establish a network of weather radars and the facilities for handling the data from the radars and from satellites. Considerable progress in this area has been made during 1979.

The coverage of the network of radars which has now been established is shown in Figure 4. Of the four radars shown, the one at Camborne was established in 1978 and those at Upavon, Clee Hill and Hameldon Hill in 1979. Qualitative coverage extends over a large part of England and Wales but London and eastern parts of England are not covered. The accuracy of the radar measurements decreases with distance and further work remains to be done to improve their accuracy even at the close ranges. Improvements will come about during the course of the next few years, initially as a result of the incorporation of real-time calibration rain-gauges and later as a result of the development of further correction procedures, many of which are likely to be applied using man–computer interactive methods implemented at a central location where the data from several radars are received, composited and analysed before being retransmitted to users. Most of the radars, although operated as nearly as possible around the clock, are experimental; however, one of them (radar 4 in Figure 4) is being established as an operational unmanned weather radar as part of a collaborative project between the Meteorological Office, the Central Water Planning Unit, the Ministry of Agriculture, Fisheries and Food, the North West Water Authority and the Water Research Centre.

Rainfall data from individual radars have been sent by telephone in digital form to one or two Meteorological Office and water authority users during 1979 and several more offices will be served during 1980. A fresh rainfall pattern is transmitted every 15 minutes. Data are also sent routinely by telephone to the

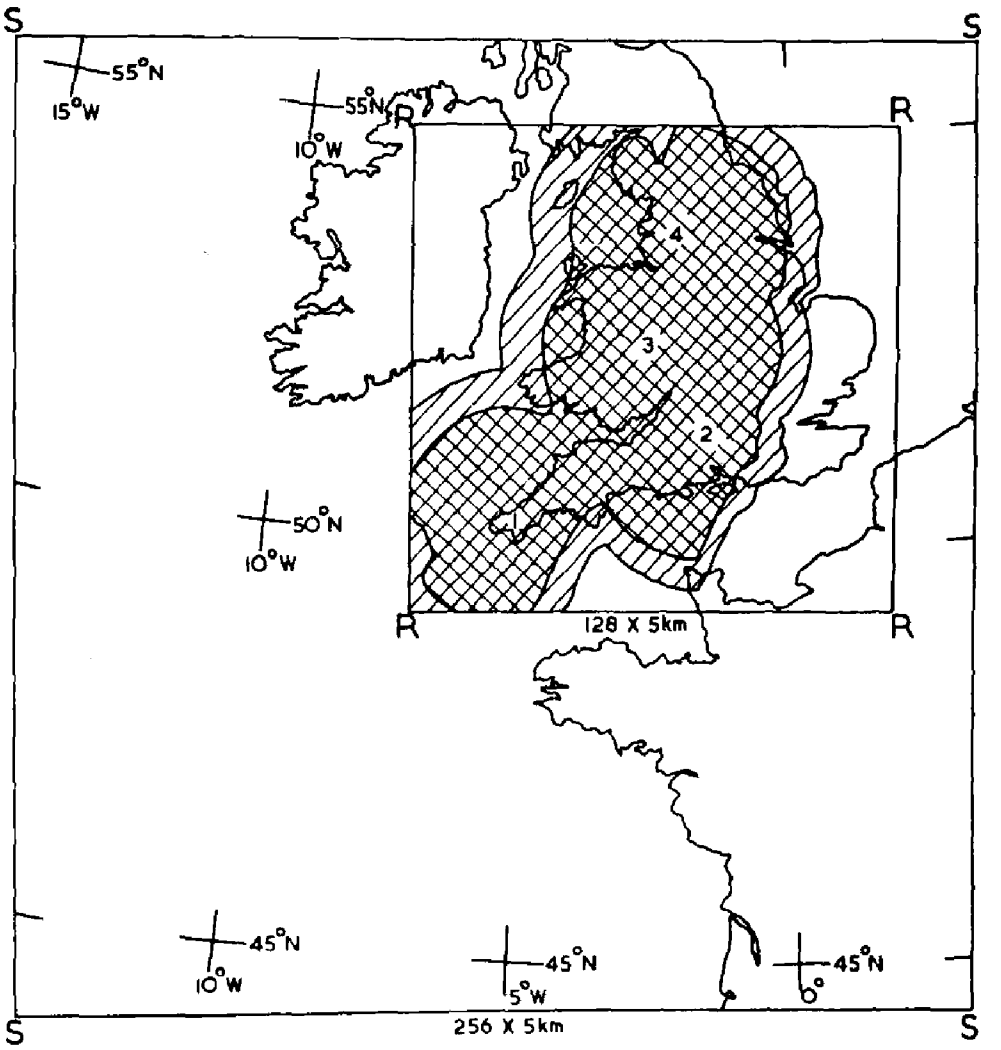


Figure 4—Coverage of the radar network and radar-compatible satellite data available in the Short Period Weather Forecasting Pilot Project

The shading indicates the approximate area within which precipitation can be observed qualitatively using radars located at (1) Camborne, Cornwall, (2) Upavon, Wiltshire, (3) Clee Hill, Shropshire and (4) Hameldon Hill, Lancashire. Cross-hatching shows the typical year-round coverage and single hatching shows the cover in summer conditions. The square RRRR denotes the boundary of the TV type display on which colour-coded digital rainfall data from the radars are combined in a 128×128 matrix of 5 km cells. The larger square SSSS denotes the boundary of the TV display on which colour-coded digital satellite cloud data are displayed in a 256×256 matrix of 5 km cells. The radar network data can be superimposed on the appropriate area.

Meteorological Office Radar Research Laboratory at Malvern where a composite display covering the area RRRR in Figure 4 is generated automatically within 4 minutes of data time. Infra-red cloud pictures, when available from the European geostationary satellite, Meteosat, are converted to a radar-compatible format at Bracknell and data covering the area SSSS in Figure 4 are received at Malvern at nominally half-hour intervals for analysis along with the radar data. Recently some visible Meteosat data have also been received and work is in progress to develop ways of combining the IR and VIS data to produce a better indication of areas of precipitation than is provided by either IR or VIS cloud data alone.

The rainfall data from the radar network and the cloud pictures from Meteosat are both displayed on colour television monitors in a matrix of 5 km squares based on the national grid. Sequences of pictures can be replayed to reveal the movement and development of weather systems. Colours on the display represent rainfall intensity in the case of the radar data and cloud-top radiance in the case of the Meteosat infra-red data. Equipment for the reception, display and action replay of a limited sequence of pictures, developed by the Royal Signals and Radar Establishment, is available commercially. This relatively simple display is already in use at some Meteorological Office outstations and by some water authorities. A computer-driven display is available at Malvern which permits the merging of radar and satellite data (in a simple way at present) and also enables long sequences of data to be replayed. This computer-driven colour television display is being used to develop and test methods of quality control, analysis and very-short-range forecasting. Over the next few years it is planned to develop methods of combining the radar and satellite data and for analysing them on the television screen itself. The resulting analysed and quality-controlled products can then be distributed to users together with the very-short-range forecasts derived from them.

Geophysical fluid dynamics

The high degree of complexity of the atmosphere tends to obscure the fundamental factors that control large-scale atmospheric motions. The main work of the Geophysical Fluid Dynamics Laboratory is intended to explore basic dynamical processes in rotating fluids, of which the atmosphere is but one example. Other natural fluid systems in which rotation plays a dominant role are the atmospheres of other planets, the oceans and the liquid core of the earth where the earth's magnetism originates.

Studies are carried out using a variety of methods, including the detailed examination of motions in rotating fluids in the laboratory, theoretical mathematical investigations and numerical modelling. The laboratory systems provide tests of mathematical theory and suggest new lines of theoretical research while the combination of laboratory experiments and numerical modelling of the same system provides a unique opportunity to subject numerical models to stringent tests which are not possible in other contexts. In the laboratory the experimental conditions can be varied over a wide range and theories thereby tested in a manner which is not possible if they are applied only to the atmosphere. We cannot change the rate of rotation of the earth to see if a theory continues to apply, but we can change the rate of rotation of the fluid container in the laboratory.

Many features of the large-scale atmospheric circulation can be reproduced in liquid filling a rotating annulus, the inner and outer walls of which are maintained at different temperatures. The transfer of heat by the fluid between these walls simulates the transport of heat from the equatorial regions towards the poles by the wind systems. The laboratory studies show that several different regimes are possible. The flow may be axisymmetric, it may contain a 'jet stream' with regular wave-like perturbations or it may be highly irregular. Experimental and theoretical studies have established the conditions under which such regimes are to be expected. The existence of many possible steady states for the same boundary conditions, 'multiple-equilibria', in the regular flow regime greatly complicates these studies.

The predictions of numerical models of the annulus flows have been compared with the results of extensive laboratory observations. Many of the observed features, such as the amplitude and structure of the dominant baroclinic wave are well predicted but although the grid can be made so fine that no parametrization of sub-grid-scale processes is necessary, there is difficulty in predicting some details of the flow, for example the structure of the jet stream. The comparative studies, which have obvious implications for attempts to model the more complex atmospheric flows, demonstrate the sensitivity of the flows to weak forcing. Attempts are being made to determine the degree of resolution and complexity which are necessary if numerical models are to simulate the observed flows satisfactorily.

Analyses of the energetics of the flows which can be derived from the numerical simulations have been continued. The results suggest that in the laboratory systems there is a near balance between the viscous dissipation of kinetic energy and its generation by conversion from potential energy even at the largest scales of motion, the precise balance being maintained by non-linear transfers of energy to other scales. The extent to which the observed regularity of the flows depends on this balance is the subject of further study. Theoretical work reported last year and now being followed up has shown that regular 'soliton' solutions may be obtained for simplified forms of the equations governing large-scale atmospheric motion. If similar solutions are valid in the atmosphere it would imply a higher degree of long-term atmospheric predictability than is suggested by most current theories. Laboratory work related to the problem of predictability has been carried out in a simpler mechanically driven two-layer fluid system in which the driving force was allowed to vary in a cyclic manner. The work demonstrated the extent to which the flow variations were predictable from a knowledge of the boundary conditions. Also related to the problem of predictability in particular to that of predicting the wavelength of baroclinic waves which grow to largest finite amplitude under particular conditions, a numerical study has been made of the initial growth of disturbances and the ways in which the mean flow is modified by the growing disturbances.

The phenomenon of vacillation, long-term periodic fluctuation in the amplitude or shape of the baroclinic waves, which is frequently observed in the laboratory, is believed to be related to the observation of 'index cycles' in the atmospheric circulation. The energetics of this phenomenon are unclear as numerical simulations of the annulus flows have failed to reproduce it. Laboratory experiments have been undertaken to determine the optimum conditions for attempts to obtain numerical simulations of vacillating flows and to obtain more data on the flow changes in order that possible deficiencies of the model may be isolated. Progress has been made in developing apparatus to study the heat transport by vacillating flows. The predictions of the complex models are being compared with those of other, simpler models, for example models in which limited numbers of waves and a restricted range of interactions are included to determine whether there are any differences in their abilities to reproduce vacillating flows.

Laboratory studies of the effects of topographic forcing on baroclinic flows in both the thermally and mechanically driven systems have demonstrated that the interactions between forced and drifting components of the motion can significantly alter the drift rates and amplitudes of the drifting components. In the

thermal system the presence of the topography stabilizes the flow so that baroclinic waves are less likely to occur (an effect previously noted in numerical atmospheric general circulation models) but when waves do occur they are usually of shorter wavelength and larger amplitude than in the absence of topographic forcing. The changes in the mean flow which give rise to these changes are being further investigated. Some preliminary studies have also been made in the laboratory on the effects of topographic forcing on predictability of the flows and results obtained so far suggest that the effects make the flows less predictable in that a greater range of dominant wavenumbers is possible for the same conditions.

Further laboratory studies of the structure of the thermocline in a rotating fluid have been made and the observations have been used to assess the range of applicability of associated theoretical investigations.

Mention has been made of various simplified mathematical models of annulus flows. A study has been made of the applicability of these models to the usual experimental arrangement in which the inner and outer walls are held at different constant temperatures. It has been found that almost all previous studies with the most widely used simplified model have not included the appropriate lateral boundary conditions. Because of the constrained and interactive character of the model it is not a straightforward matter to change these conditions whilst retaining dynamical consistency. However, an improved formulation has been proposed and subjected to detailed theoretical scrutiny. It shows considerable promise but confirmation of its utility must await the outcome of numerical tests.

In the field of theoretical geophysics and magnetohydrodynamics, the developments reported last year have led to new work concerning the self-exciting dynamo process responsible for the generation of the earth's magnetic field.

Finally, we report some new work on fluctuations of the total relative angular momentum of the atmosphere, which produce very tiny but detectable (by astronomical methods) fluctuations in the length of the day. In collaboration with the Dynamical Climatology Branch we have made use of the new meteorological data from the First GARP Global Experiment program and found evidence of irregular changes of up to 15 per cent in atmospheric angular momentum over time intervals of about ten days. Good correlation of these changes with independently measured length-of-day fluctuations has recently been established by L. V. Morrison of the Royal Greenwich Observatory.

Dynamical and Synoptic Research

Research related to numerical short-period forecasts

The Global Weather Experiment (see page 113) has highlighted the radical changes that have come about in recent years in the technology of making meteorological observations. An important contribution towards improving the accuracy of short-period forecasting is the development of a new weather-prediction system which takes more advantage of the information available from new observing systems. Formerly, observations from ground level up to the high stratosphere were made at internationally agreed synoptic hours only, using

instrumentation which gave direct measurements of the meteorological variables—temperature, humidity, wind and pressure. Modern technology, however, has led to the use of a wide variety of instrumental techniques to supplement the existing network. The new techniques often differ from the old in not measuring the meteorological variables directly—measuring infra-red radiation rather than temperature, for instance. They can give more observations than the old methods, by using continuously operating instruments on moving platforms such as satellites, aircraft, free-floating balloons and drifting buoys, though only a few may be made close to the synoptic hours.

The current operational numerical weather forecasting procedure, which was designed for a conventional observing network, consists of three distinct stages. Observations of the pressure field provide data for estimating values on a regular mesh of grid points with a 300 km separation and covering the earth's surface north of latitude 15°N. Only observations at or near the main synoptic hours (midday or midnight) are used. Wind measurements affect the result only indirectly, by allowing estimates to be made of the local pressure gradients. The next stage of the operational forecasting procedure, known as initialization, consists of calculating the wind at each grid point from the pressure field in such a way that the initial state is 'balanced'; i.e. rapid changes (from both real and spurious causes) will not occur at the beginning of the subsequent forecast. The forecast itself is performed by a numerical model based on the equations of motion and thermodynamics for the atmosphere. Results are obtained at 10 fixed pressure levels for periods of up to 6 days.

The proposed new forecasting system is being designed so that observations made throughout the day may be used effectively. It is based on the scheme which was tested successfully during the Special Observing Periods of the Global Weather Experiment. Observations of temperature, humidity, winds and surface pressure are collected together for periods throughout the day (6-hour periods were used during the Global Experiment) and values of each variable are estimated at a mesh of grid points which, for the new forecasting system, may cover the whole earth. The interpolation to grid points is different from the method used in the current operational scheme, being able to take into account differing error levels of each observing technique. Errors in measurements are partly instrumental and partly due to the unrepresentativeness of point observations. There is an additional difficulty in using some new techniques because the required meteorological variables have to be estimated indirectly from observations of other atmospheric features—winds are estimated by tracking the movement of clouds on sequences of satellite photographs, for example. The grid-point estimates are assimilated by using the numerical forecasting model to predict the atmospheric flow a short time ahead, then taking a weighted average of the results of the forecast with the interpolated values, and continuing the forecast for a second time-step. By repeating the procedure and gradually increasing, over the period of an hour or so, the relative weight given to the observations, the state of the model is steadily guided towards that of the atmosphere. The observations are then replaced by a more recent set and the procedure continued. A forecast for longer periods can be produced at any time by integrating the model forwards without including any new observations. The technique has the advantage of producing a continuous up-to-date analysis of the atmospheric motion, and of requiring no initialization stage which, in rapidly developing situations, may adversely affect the quality of the forecast.

In the first implementation of the new system, the temperature, humidity, wind and surface pressure will be analysed independently before assimilation into the model. Later, it is hoped to introduce an improved scheme for the simultaneous analysis of the meteorological variables in such a way that observations of one variable can influence the analysis of others by means of simplified dynamical constraints. Test analyses of this sort have been produced during the year, but further experiments are needed to optimize the choice of a number of parameters within the scheme.

The heart of the new forecasting system is the numerical model. Over the past few years an extensive series of tests has been undertaken to examine the different characteristics of a variety of numerical schemes for solving the equations of motion and thermodynamics. They have demonstrated that a number of schemes are suitable, no one producing forecasts substantially more accurate than the others. Consequently the new model will use a method developed from the current operational scheme, as it is particularly efficient in terms of computer time. Although the data assimilation procedure will probably cover the whole globe, the subsequent forecasts will be for the area north of 20°S, since it is unlikely that atmospheric motion south of this latitude will have a noticeable effect on the weather in the northern hemisphere over a period of a few days. The number of levels in the new model will be about 15, an increase from the present number 10. This will permit increased resolution close to the ground and near the level of the jet streams, and a representation of motion in the stratosphere. The horizontal grid length will also be reduced and improved methods of parametrizing sub-grid-scale physical processes, similar to those used in general circulation models, will be introduced.

In parallel with the development of the new model, a number of longer-term research projects have been pursued. It is hoped that they will provide the basis for further improvements in the new forecasting system in coming years. An investigation into the basic dynamical processes as represented by the forecast models has put particular emphasis on the local vorticity and thermal vorticity budgets, and on the ways in which the atmosphere adjusts to rapid changes. Other research topics include studies of the effect of having an explicit representation of the tropopause in the model and studies of the structure, development and interaction of long waves in a zonal flow.

The expense of providing a world-wide atmospheric observing network has led to questions concerning the design of the most cost-effective system. The Global Weather Experiment will provide data for investigations. At the end of 1978 an experiment was conducted to assess the importance of the North Atlantic weather ships on numerical weather prediction. Two parallel analysis/forecast cycles were run for a three-week period using the current operational forecasting and analysis system. One contained data from the weather ships and the other did not. The results showed that the omission of the data had an overall deleterious effect on both the analyses and the forecasts. Although, when assessed as an average over the experimental period, the amount of degradation was small, large errors arose in individual cases.

Quantitative prediction of precipitation by numerical models is of immense practical importance. The success of the operational fine-mesh model in this respect has been assessed by examining the errors in the rainfall amount forecast for each day over a 6-month period for 37 one-hundred-kilometre-square areas covering the United Kingdom. The results indicated that, on the

whole, the model tends to underestimate the rainfall, the largest errors being in mountainous regions. For example, in the square composed mainly of the Central Highlands of Scotland, the average predicted rainfall was less than 50 per cent of that estimated from observations. This indicates that to make the rainfall predictions more accurate, it is necessary to improve the computation of the orographic component of rainfall. Several ways of improving rainfall forecasts in mountainous areas have achieved some success in trials, although it is not yet clear which of the methods is best. It is known, from experiments conducted elsewhere, that reducing the horizontal grid length tends to increase the forecast amounts of rainfall. It is difficult to assess the importance of this effect using the operational fine-mesh model since most of the forecasting area lies over the Atlantic where there are no rainfall observations against which the forecasts can be verified. This problem has been resolved by developing a movable limited-area fine-mesh model which is now being used in a series of forecasts over North America with various grid lengths. This model is also being used to investigate the structure and flows within both real and idealized baroclinic waves. The structure of the flow in the vicinity of cold fronts has also been investigated, both by analysing the observations in detail and by attempting to reproduce the main features in a two-dimensional model. The dynamics of the low-level jet ahead of the cold front are being given particular attention. The experience gained from these and other investigations will be used in designing a new operational fine-mesh forecasting model.

Very-short-range local weather forecasting requires a different approach and a limited-area ultra-fine-mesh model is being developed for this purpose. During the past year several aspects of an analysis/forecast cycle have received increased attention. An experiment which was designed to give an indication of which features of the initial conditions are important for accurate prediction of the subsequent mesoscale development has been completed; it appears that for a sea-breeze it is important to ensure that the initial temperatures are accurate. Work is under way to develop a complete and flexible mesoscale initialization scheme. The ability of the model to describe the effects of orography faithfully, especially lee waves under a variety of conditions, is being tested. This work also provides valuable guidance about various technical aspects of the model, including the formulation of the lateral and upper boundary conditions. It is intended to improve the physical description of turbulence and a survey of present methods for treating this problem is in progress. Mesoscale investigations of particular cases are being carried out, including two forecasts that have been made for the day of the Hampstead storm (14 August 1975). The main conclusion of this study is that it is possible to provide an explanation for the mesoscale convergence zone apparently responsible for triggering off the storm on that day, if account is taken of the important effects of a layer of stratocumulus cloud spreading across the country on the surface exchanges of heat and momentum.

In examining errors in the current operational model, it has been found that the 12-hour forecast errors are related to errors made in previous forecasts. An investigation is under way to see if errors for as long as three days ahead can be represented in terms of past errors by means of more elaborate transfer functions. If this proves possible, it may be feasible to predict certain errors in the model and to make compensating adjustments to improve the quality of the forecasts. On a more subjective level, a regular assessment is being made of the

behaviour of the operational model by comparing synoptically its forecast charts with those which the European Centre for Medium Range Weather Forecasts (ECMWF) began to produce daily in July. The primary aim of this work is to assess the usefulness of the ECMWF medium-range forecasts, but the regular comparison of two different models has proved to be very useful in highlighting their different characteristics.

General circulation of the atmosphere

Research has continued on the development of numerical models capable of simulating the atmospheric general circulation, both for extended-range forecasting and for modelling climatic change. Two basic models have been used, a medium-resolution model with 5 layers and a grid mesh of about 330 km, and a high-resolution model with 11 layers and a 220 km grid mesh. A low-resolution version of the 5-layer model with a 500 km mesh is also available. The models can be either hemispheric or global. The hemispheric versions have been used mainly for studies of extended-range forecasting, where real initial data which have generally been available only for the northern hemisphere are required. During the year, however, the Global Weather Experiment has provided a valuable series of global data sets.

A new version of the 5-layer medium-resolution model in which the horizontal resolution in high latitudes is enhanced to reduce the truncation errors associated with the large curvature of the latitude–longitude co-ordinate system near the pole has been tested. The Arctic anticyclone which was previously a persistent feature of simulations was removed but not all the changes were for the better.

The 11-layer model has been adapted so that it can be run on the powerful CRAY-1 computer at the European Centre for Medium Range Weather Forecasts. The Office has an allowance of time on this computer and it will be possible to run the model for long enough to study its simulations of seasonal variations.

The integration of the 5-layer, medium-resolution model with a seasonal variation has been continued through a second year to allow assessments of the model's interannual variability, including an evaluation of two relatively new features—treatments of snow cover and soil moisture. The simulated seasonal variation of snow cover is realistic, with melting of snow by late summer in all areas except those with permanent ice-caps and an expansion to near 45°N over most of the continents in winter; however, central North America has too little snow. Relatively dry areas corresponding to the major deserts are maintained, although the extreme aridity which is observed is not consistently simulated in summer. The model's surface is generally too wet, particularly in middle latitudes.

Anomalies of soil moisture content tend to persist because continental precipitation depends largely on local evaporation, which itself varies with the soil moisture content. This was well illustrated by 50-day experiments with both low- and medium-resolution 5-layer models starting from very dry and very wet initial conditions over most of Europe south of the Baltic. Averaged over the last 30 days, rainfall was four times less when the experiment started with a dry surface than when it started with a wet one. From earlier experiments with a limited-area version of the 11-layer model a similar persistence of anomalies was expected to occur over North Africa. However, in simulations with the global

version for the northern summer the Sahara, though dry initially, was found to become unrealistically wet after about two weeks. A series of sensitivity experiments established that the aridity of the Sahara can be maintained if the initial moisture content of the soil *and* atmosphere are realistically low and the model's radiative processes are made to depend on the modelled atmospheric water vapour. A similar sensitivity of Saharan aridity to the radiation has been found in the 5-layer model.

Until now soil moisture has been represented only rather crudely in the models. Because of its importance, experiments are being done with more elaborate, multi-layer soil models to determine the degree of detail that needs to be included in representations of the full climate system.

The turbulent transfer of heat, moisture and momentum between the surface and the top of the atmospheric boundary layer presents very difficult modelling problems, and their correct solution can be of great importance in investigations of climatic change. The vertical resolution of the 11-layer model is finer in the boundary layer than at higher levels so that it is particularly suitable for the development of new approaches to the problem. During the year there has been further development of a treatment which considers the boundary layer as a well-mixed slab and includes a predictive equation for the height of the boundary layer top. The response of the large-scale flow to the treatment of boundary layer processes by this scheme and another new scheme, with a different formulation of vertical diffusivities from that previously used, has been examined. As well as studying the response of the full 11-layer model to different schemes, the sensitivity of the evolution of simple initial flows has been studied. A series of integrations has been run from a baroclinically unstable zonal flow on which a small perturbation of wavenumber eight is imposed. The initial growth of the wave while still small enough to be governed by linear theory was monitored in some detail before the integrations were continued into the finite-amplitude stage of the disturbance's development. The analysis seems likely to provide a basis for identifying aspects of the boundary layer and its processes that need to be modelled explicitly and for discriminating between different boundary layer schemes.

Thermal and orographic forcing by oceans, continents and mountains are important in climatic simulations. General circulation simulations with the ocean temperatures prescribed have been carried out for a number of years to investigate the thermal forcing of the oceans. The effects of tropical sea surface temperature anomalies on middle-latitude flow have been noted in previous *Reports*, particularly the association between warm water in the tropical Atlantic and anomalies in the pressure distribution over the north-east Atlantic in winter, with pressure below normal south-west of Britain and above normal north of 60°N. This association was observed again during the 1978–79 winter and further experiments were made to assess the effect of the observed sea surface temperature anomalies in the 5-layer model. In the experiments run so far, the model was successful in predicting large falls in pressure to the south-west of the British Isles but not the rises to the north.

During the year a detailed comparison of the time-averaged long-wave features generated by the general circulation models was completed. It was noted that in several integrations with the 5-layer model with a rather smooth specification of the orography the ridge of wavenumber one tilted eastward with height in middle latitudes. This is not in accord with observation and might have

been attributed to effects of the poor vertical resolution in the stratosphere as discussed in the *Annual Report 1978* (page 104). However, analysis of a series of experiments with higher mountains showed that in these there was a realistic westward phase tilt with height of the longest wave. Such results have prompted a more intensive study of mountain effects in the models and, as a first step, a series of experiments have been planned with various idealized orographic distributions.

Climate modelling

The general circulation models that have been used so far provide a reasonably realistic representation of the present climate, but they have to be supplied with values of the ocean surface temperature and the cloud distribution taken from present-day climatic observations. If the models are to be used to predict changes in climate that may be caused by man's activities—and there is little prospect of making reliable predictions by other means—they must be extended so that the clouds and ocean temperatures are predicted by the models themselves. Such a model is said to be 'interactive'. The development of a fully interactive model which includes the whole climate system—atmosphere, land, ocean and sea-ice—will be a lengthy process but steady progress is being made. In particular, work previously reported on the modelling of the upper layers of the ocean and on a scheme for calculating clouds from the atmospheric model has been continued and extended.

In an interactive model the accurate representation of radiative exchanges is much more important than in one where ocean temperatures are fixed. In the past year a detailed comparison has been made between observed data and the 5-layer model's radiation budget through the course of an annual cycle. This has shown that the global annually averaged outgoing radiation is slightly larger than the incoming, even though atmospheric and land temperatures tend to be too low. Thus a climate model run with the present scheme would become too cold. The model's simulation of the latitudinal variations is generally realistic but this is partly due to the use of prescribed cloud amounts varying with latitude and season; longitudinal variations in cloudiness, such as that between the clear skies over Africa and the clouds over southern Asia in summer, have not been represented in the model.

The human activity most likely to affect climate noticeably is the burning of fossil fuels, releasing carbon dioxide into the atmosphere. Despite the inadequacies of present models, an experiment was run to obtain some indication of the nature of regional variations to be expected in the response to an increase in carbon dioxide. The present carbon dioxide was assumed to be doubled and the ocean surface temperatures to be 2 °C warmer, this value being obtained from simple interactive models. Important results of the experiment were that though precipitation was increased by 7 per cent in the global average there were large areas with reductions in rainfall, the increases being concentrated over the mid-latitude oceans in the winter hemisphere and in low latitudes, particularly near the east coasts of continents in summer. It was also interesting that the average warming of land surfaces (2.7 °C) exceeded that imposed over the oceans.

The ability of general circulation models to simulate the tropical atmosphere has been further studied. Previous results, based on days 21–50 of an integration with July climatological values of sea surface temperatures and solar radiation,

showed that the 11-layer model could produce a realistic representation of the large-scale wind regime of the south-west monsoon. The introduction of a new convective parametrization scheme, which provides a more explicit representation of the deep cumulonimbus clouds characteristic of tropical weather systems, has produced an improvement in this wind flow, particularly in the simulation of the monsoon trough over India. The model's monsoon circulation is also sensitive to the parametrization of radiation; the use of an interactive radiation scheme, which links the radiative processes with prevailing model conditions, has produced an intensification of this monsoon trough. No experiments to date have succeeded in developing transient monsoon disturbances such as Bay of Bengal depressions, although if such depressions are present in initial states obtained by the analysis of observations the model can predict their movement and the associated rainfall fairly well.

Global Weather Experiment

The operational phase of the First GARP Global Experiment (FGGF) started in December 1978 and ran throughout 1979. During this period the global observational network was maintained at a higher level than ever before through the use of additional ground-based stations, new satellites and automatically reporting drifting buoys. Particular effort was concentrated in two Special Observing Periods (SOPs), 5 January–5 March and 1 May–30 June, during which the already enhanced global data coverage was further improved, particularly in the tropics, through the use of additional weather ships, constant-level balloons and dropsondes deployed from aircraft.

In association with this international experiment the Meteorological Office ran a global objective analysis/forecast cycle during the two SOPs, using all the observational data which became available in real time via the global telecommunication system. The analyses were made at 6-hourly intervals (00, 06, 12, 18 GMT). The numerical forecast model used was the 11-layer general circulation model. The purposes of this work were firstly to assess the analysis technique, which had previously been tested for a brief period only; and secondly to provide global analyses for subsequent research. Analyses for the four months of the SOPs were successfully produced and were continued to include July, to permit study of the south-west monsoon. The results confirmed the indications of the earlier trial—namely that the analysis technique is encouragingly successful. The method of analysis differs from that now used in the Office's forecasting system in that it can be applied not only to middle and high latitudes but also to the tropics. It produces a direct analysis of winds rather than a wind field diagnosed from a geopotential analysis. This latter feature is important in connection with the ageostrophic effects at the entrances and exits of jet streams. Such features are likely to be advantageous in future operational analysis systems.

For SOP2 it was possible to refine the analysis method on the basis of statistics calculated during SOP1. Since the end of SOP2 further refinements have been made and work on various aspects of the technique is continuing.

As a first step to using the analyses for research with the 11-layer general circulation model, a daily catalogue of charts has been produced, together with other diagnostics such as time-averaged fields, meridional cross-sections and kinetic energy profiles. Some of the diagnostics, particularly those relating to the hydrological cycle of the model, have revealed shortcomings in humidity data

and in the treatment of soil moisture content which were not evident in the daily sequence of analysed charts.

Consideration is now being given to the most effective means of assessing the importance of particular components of the observing systems such as satellite temperature soundings, ocean weather ship observations and aircraft wind reports. One requirement in such work is to have the best possible analyses to use as 'ground truth'. The global analyses produced in real time lacked data collected in delayed mode and programs are now being written to provide revised analyses for selected cases of interest, which will include these data.

Stratospheric research

Diagnostic studies of the stratospheric warming events simulated by a 13-level general circulation model have continued. They have provided further support for the suggestion, previously based on observational studies of the 1976/77 winter, that meridional transports of momentum associated with planetary-scale wave motions play a fundamental role in the dynamics of stratospheric warmings. A paper has been written in which a mechanism is proposed by means of which a flux reversal, producing equatorward eddy momentum fluxes, might occur in the stratosphere.

Two dynamical models are being developed as tools for research into stratospheric dynamics. The first is a linearized planetary wave model which provides a diagnosed latitude–height structure of stationary planetary waves for given zonal wind distributions. The numerical calculations have been checked for cases where analytical solutions may be obtained, and the model is now being applied to more realistic zonal wind distributions which cannot be treated analytically. The second model is a three-dimensional primitive equation model of the stratosphere and mesosphere with its lower boundary at 100 mb. At present the model is being tested with idealized height and temperature fields specified at 100 mb, but later it is planned to use 100 mb fields derived from observations. It is hoped that this will enable investigations of stratospheric dynamics to proceed without the computational expense of a model which includes the troposphere also.

Research related to long-range forecasting

Forecasts for 30 days ahead have been issued at the beginning and mid-point of each month. Each forecast contains information on the general character of the expected weather over Britain and the associated temperature and rainfall. The format of forecasts for the general public has remained unchanged and, for each of ten districts of the country, temperature is specified in terms of five categories and rainfall in terms of three categories, each of which, based on past data, is equally likely to occur. In addition, and depending on the time of year, a general indication is given of the likely incidence of frost, fog, snow, gales and thunderstorms. Subscribers to the full published version of the forecast receive a document entitled *Monthly weather survey and prospects* which also provides climatological information relevant to the time of year and a description of the weather of the previous month.

For some commercial customers forecasts are provided in special formats designed to provide the best possible guidance in relation to the customer's particular requirements. Forecasts may be given in terms of the probability of

occurrence of particular ranges of temperature or rainfall, for example, or they may cover mainland Europe rather than Britain.

The forecasts are derived from a combination of statistical methods which compare what happened in the past with current developments. These methods have been added to or developed in several ways in the past year. The selection of 'analogue years', in which the weather resembled that of the recent past, has always been important but last year a larger number of analogue years were taken into consideration to provide some indication of the probability distribution of expected outcomes. Much use is made of the representation of pressure fields by a small number of 'principal components' or eigenvectors. Multiple regression techniques have been used to predict the coefficients of the eigenvectors in the future, with some limited success, and attempts are being made to improve the techniques. In another method, the series of eigenvector coefficients are examined by spectral analysis and continued into the future by extrapolating the dominant components.

As usual, the forecasts issued have all been carefully assessed for accuracy—in objective terms as far as the forecasts of temperature and rainfall are concerned and by the subjective assessment of an independent panel for the 'additional information'. In addition the success of the individual techniques used in preparing the forecasts has been monitored. None is consistently more reliable than the others. The overall success of the temperature and rainfall forecasts has remained only modestly better than chance but the standard of the 'additional information' contained in the forecast has been as high as in any of the last ten years.

The work on long-range forecasting would be impossible without adequate sets of data on past weather. Much effort has been put into assembling and maintaining the 20 or so major data sets now used. New data are added continually, after undergoing careful quality control, and temporal and spatial gaps are filled in as a result of a continuing search for reliable records, often in collaboration with other meteorological services. Special attention has been paid to data on sea surface temperature; in addition to the 40 million ships' observations now assembled, observations from weather satellites are now also being received.

The fact that meteorological observations are now regularly used as input to global numerical models of the atmosphere for forecasting purposes, makes it fairly easy to obtain not only values of the observed meteorological variables but also values of derived quantities describing important features of the circulation, for instance the zonal and meridional components of kinetic energy. The study of fluctuations in these quantities on time-scales from days to months will be useful to long-range forecasting. The European Centre for Medium Range Weather Forecasts uses a global model daily and in collaboration with the Centre and Reading University a study on these lines has begun.

Application of dynamical methods to long-range forecasting

Considerable practical experience has been gained during the year in running the general circulation model in a semi-operational mode in support of long-range forecasting. Integrations have been carried out at least once or twice a month using real initial data. Most of them have been run to 50 days and comparisons made with runs using, for instance, climatological sea surface

temperatures. The results are being analysed quantitatively and the production of a detailed and consistent climatology of the model is almost complete. Occasions when the model produced particularly interesting developments, for instance blocking over Europe, are being investigated in more detail, in order to try to understand why they occurred.

Studies of the large-scale circulation of the atmosphere

The study has continued of the relations between tropospheric weather sequences in the northern hemisphere and the cycle of the stratospheric quasi-biennial oscillation (QBO). A set of indices representing the main features of the atmospheric circulation over the Atlantic and western Europe together with the temperature and rainfall over England and Scotland has been related to the phases of the QBO since 1954. A parameter has been derived from these indices whose value month by month sums up the main features of the tropospheric flow and the weather conditions near and over Britain. Positive values correspond to stronger westerlies in high latitudes, increased anticyclonicity, and (usually) warmer weather. Its value month by month has been found to show a significant quasi-biennial oscillation throughout the past 90 years, and thus enables the phases of the stratospheric QBO to be inferred prior to the availability of upper-air data. The periods vary from 20 to 36 months, and average about 26 months. Because the periodic component of this parameter can be extrapolated into the future, it provides useful guidance in seasonal forecasting.

A project to form a set of monthly (and later daily) indices of flow and vorticity over Britain and the North Sea for the past 300 years has been extended and now forms part of a research contract for the Department of the Environment. It includes the monthly mapping of mean flow patterns from 1660 onwards for the North Atlantic–European area, and relating these patterns to variations of temperature and rainfall in western Europe, in particular to variations of extremes. Monthly surface pressure maps are being prepared from 1814, a date from which there is a useful network of pressure observations including Iceland and Greenland. Work is almost complete on the derivation of maps of anomalies of surface pressure characteristically associated with readily identifiable distributions of temperature and rainfall over the area, and these will be used to make the best possible inferences from the much scantier data back to 1660.

The daily catalogue of central England temperature has been used to prepare tables showing various statistics of the departures from normal over monthly and other periods. These have been used to make an initial analysis of variations in seasonal extremes of temperature since 1660. From the regional, daily and monthly catalogues of rainfall over Britain an analysis of recurrence intervals of drought years has been made for the Thames Water Authority.

Studies have continued on the antecedents of 'blocking' over the east Atlantic and western Europe. A statistical analysis of the occurrence of blocking in this area over the last 30 years has indicated coherent changes in the 500 mb flow around the hemisphere over periods up to 45 days prior to blocking. An experiment in the prediction of blocking up to 20 days ahead using these indications showed a useful improvement over chance in November and December but no apparent skill at other times of the year. Combining the statistics of the 500 mb flow with other known precursors of blocking may, however, produce more positive indications and work is continuing. Possibilities for

the prediction of blocking by dynamical methods using the 5-level general circulation model are being investigated. So far two experiments have been undertaken to study the possible role of forcing by anomalous gradients in sea surface temperature over substantial areas of ocean. Anomalous cold and warm water in the central Pacific Ocean produced a blocking situation in the European sector 15 to 20 days after model initialization. This blocking was not evident in a parallel control experiment using normal sea surface temperatures in ocean areas.

Climatic change

Various studies have been undertaken to consolidate and extend our knowledge of the behaviour of global and local climate over the past hundred years or so. An examination of the variations in strength of the North Atlantic westerlies produced some interesting results. Their strength was estimated in terms of the difference in mean-sea-level pressure between the Azores and Iceland. The changes found were mainly in winter, and consisted not only of trends in the mean strength of the westerly gradient and its variability but also of substantial changes in the shape of the frequency distribution of the values of the pressure differences. This appeared to be bimodal, one peak corresponding to strong westerlies and one to weak westerlies, the latter probably relating to increased blocking in the North Atlantic. The frequency of this blocking mode was least in the early twentieth century, somewhat greater in the late nineteenth century, and greatest in the period since 1940. It appears that the changes reflect adjustments of the probability of selection of the Atlantic sector, as opposed to the Pacific sector, as the major route for heat transport to the Arctic, the most likely cause being variations in the sea surface temperature.

A study of monthly and annual grid-point data sets of 500 mb and 700 mb geopotentials, and 1000–500 mb thicknesses over the northern hemisphere north of 20°N has revealed that there are considerable differences between the analyses produced by different countries. The differences are largest over the oceans, the subtropics and the Arctic and make it impossible to detect any trend in areally averaged temperatures in the lower troposphere during the 1970s. A start has therefore been made on the creation of a fully quality-controlled set of monthly mean data from a selection of stations representative of as large a part of the hemisphere as possible. This should make it possible to examine the variability of mean temperature in this part of the globe more closely and determine trends more precisely. To extend the work to the tropics and southern hemisphere is probably impossible, at least before about 1974 when data from satellites became available.

With regard to more local changes over Britain, the long-period daily record of central England temperature, now available from 1814, is being examined for climatic variations in relation to various weather types using the Lamb daily catalogue, which goes back to 1861. A study has already shown, for instance, that the overall warming evident in October has been accompanied not only by an increased frequency of southerly types, but also by a warming of westerly types. Whether this latter trend has been due to a change in trajectory of the air reaching Britain or to a warming of the ocean over which the westerlies pass is not yet known.

Special investigations

Many requests for meteorological advice need work going beyond the routine extraction of data or the straightforward application of meteorological theory. Unless they are so specialized as to require the attention of one of the main research branches, such requests are handled in the Special Investigations Branch, which has built up considerable expertise in the assembling of fact and theory from diverse sources and their application to practical problems. Most of its investigations have been connected with aviation, but the proportion of non-aviation enquiries has increased in recent years.

One of the most important aviation-related subjects studied is the effect of low-level variations in wind, particularly on the handling of large jet aircraft. In 1977 a method of giving warning of the likelihood of 'wind shear' was tried out. Results from the flight records of several hundred landings or take-offs made during the trials are still being analysed, but subjective reports from pilots already show that the method had appreciable success—enough for British Airways to request the provision of an operational service based on the method used during the trials. Another problem is the difference which may exist between the wind at the anemometer, usually centrally sited, on an airfield and the wind actually experienced on the runway, which may be up to 3 km away. To study such differences automatic digital recording equipment has been attached to two anemometers 3.2 km apart at London/Heathrow Airport and has been in full operation since August 1979. In a parallel investigation the structure of wind squalls at Heathrow is being studied, with the aim of improving the realism of input to aircraft simulators used for training. The Civil Aviation Authority has set up a working group on the reporting of surface wind to influence the implementation in air traffic control procedures of results reached by these and other studies.

The increasing use of helicopters in adverse winter conditions, particularly in a rescue role, has led to a need for better information on the probability of encountering severe icing or heavy snow conditions. This is being met by a program of observations from the MRF aircraft and by assembling appropriate climatological data. One very valuable set of data comes from the cloud observations from a series of meteorological reconnaissance flights made during and immediately after the 1939–45 war. This unique body of data is being put into machinable form for further use.

A long-standing problem is that of clear-air turbulence (CAT), which can cause discomfort and on occasions injuries to airline passengers. Details of the occurrence of CAT during about 5000 flights were collected on ten reporting days in 1976 and have now been analysed. Multiple regression techniques were used to identify the most relevant meteorological parameters and a method was devised for obtaining these parameters from the operational numerical forecasting model and combining them to give an objective forecast of the probability of encountering CAT. Preliminary tests suggest that this method is more successful than the methods currently employed.

A method of forecasting the intensity of convection over the United States by direct computer processing of upper-air data has been successfully developed for flight-planning purposes at London/Heathrow Airport. This is now undergoing operational trials and, if accepted, will eliminate the need for manual plotting of American upper-air data.

The Office has a representative on the Civil Aviation Authority Data

Recording Panel which examines flight data records from about 40 aircraft in civil transport service to search for abnormal flight behaviour. The object is to identify potential causes of accidents and introduce appropriate changes in procedure.

A small team helps and encourages investigations carried out at outstations, mainly in relation to the forecasting of local weather. Computer services for the provision of data and guidance on methods of analysis and interpretation of results are given. These services are also provided for student projects at the Meteorological Office College. This year, the development of schemes for forecasting thunderstorms in north-west England and fog at Finningley showed considerable promise, and may have a wider application.

Methods of providing quantitative forecasts in the form best suited to individual users—usually by giving the probability of specific events—are being developed. Clear-air turbulence is one example. Another is the objective forecasting of temperatures up to five days ahead to help the gas and electricity supply industries. The sensitivity of gas demand to various meteorological parameters is being studied so as to find the optimum combination of forecast parameters for use by British Gas in predicting the next day's demand. An objective method of forecasting the probability of rainfall up to three days ahead has been developed but it has met with only limited success.

A large number of enquiries about pollution have been answered, mainly from firms in the chemical industry who wish to know about the likely spread of chimney plumes or to plan emergency action in case serious leakage of dangerous chemicals should occur. This work depends, among other things, on the assessment of atmospheric stability, and a re-examination of the suitability of the indices used to specify this stability has begun.

Enquiries have also been answered on the effects of precipitation and of particular temperature and humidity conditions on microwave communications links.

Library, Editing, Publications, Archives and Cartographic Section

The National Meteorological Library forms part of the Meteorological Office Headquarters at Bracknell. It is used mainly by the staff of the Office but there is also a large demand for its services from universities, schools, commercial and industrial firms and the general public.

The first, accessions, stage of the Meteorological Office Library Accessions and Retrieval System (MOLARS), briefly described in the *Annual Report* 1978, has continued to work very satisfactorily and has aroused interest in library circles particularly because of its relatively smooth entry into service. Visitors connected with the libraries of Swiss and Dutch meteorological services were impressed by the system and commented on the feasibility of extending it to give a European service.

The equipment necessary for the second, retrieval, stage of MOLARS has been received but will not be introduced into service for some time because of the shortage of programming capability.

The number of accessions to the Library during the year was similar to that of 1978, but the number of loans fell slightly after the record level of that year. Enquiries covered their usual wide range, from rainfall in the Solomon Islands to

the weather during the summer of 1643 and its possible effects on the Civil War.

In the Visual Aids section efforts continue to update and expand the collection and over 1000 items were taken in during the year. Loans from this section also increased considerably, partly owing to the extra demand for satellite cloud photographs. The use made of the common service for the printout from computer output on microfilm has increased threefold and places further strain on accommodation.

As staffing permits, updating of some exchange arrangements has been made, particularly with Commonwealth countries in East and West Africa and with Cyprus and Malta.

Co-operation with other Government and local libraries continues, giving savings in time and money.

The Editing Section remains responsible for preparing for printing most of the official publications of the Office, and co-operates closely with Her Majesty's Stationery Office in the maintenance of publishing standards. A new publication entitled *Monthly and annual totals of rainfall for the United Kingdom* has filled the gap caused by the decision to abandon the publication of *British Rainfall*. Copies for 1969 and 1970 have now been issued.

Works published during the year are listed in Appendix III; they include the *Meteorological Magazine*, a monthly journal containing short scientific articles, reviews and items of interest to meteorologists everywhere.

The distribution of publications, both official and commercial (scientific journals, textbooks, work of reference, etc.) to the Office's many outstations, is under the control of the Publications Section, which is also responsible for the half-yearly issue of some 350 000 observation forms of all kinds to over 6000 reporting stations.

Meteorological observations in manuscript and other original documents and records are kept, in accordance with the Public Records Act 1958 and the Public Records (Scotland) Act 1937, in special repositories (archives) in Bracknell, Edinburgh and Belfast. The material in these archives is consulted by a large number of people, from both inside and outside the Office. During the year, 400 loans were made from the archives at Bracknell. This is rather less than in previous years owing to the increasing use being made of computer-held products.

The Cartographic Section prepares diagrams for Meteorological Office publications, for internal memoranda and for papers contributed to scientific journels by members of the staff. It also prepares data-entry forms, exhibition displays, lecture and training viewfoils and slides as well as the many charts and diagrams for various areas of the world that are used for plotting meteorological observations.

Statistics on the work of the Library, Archives and Cartographic Section are given in Table XVI (Page 125).

Professional Training

Policy on the professional and managerial training of Meteorological Office staff is determined by the Meteorological Office Training Board, under the chairmanship of the Director-General. Most of the formal professional training is carried out at the Meteorological Office's own residential College or its School

of Technical Training. Some staff, however, attend specialist courses outside the Office. The College maintains contacts with neighbouring Colleges of Technology, the University of Reading, the European Centre for Medium Range Weather Forecasts (which is next door), the British Council, the Royal Naval School of Meteorology and Oceanography and other relevant bodies.

The Meteorological Office College is situated at Shinfield Park, south of Reading. It accommodates just over 100 students and carries out training in basic meteorology as well as in forecasting, observing and related topics. The College is well equipped for class-room teaching, for field-work, for the analysis and use of meteorological charts and for briefing training, including the use of closed-circuit television and videorecording. It has a cinema which seats 94, two lecture theatres and 13 class-rooms, including one designed for tuition on instruments. An important part of many courses is the simulation of the working conditions in operational forecasting offices. For this purpose, current meteorological observations from many parts of the world, including those obtained from satellites, are received by teleprinter and by facsimile.

The grounds of the College provide room for field-work, the siting of instruments and for relaxation. College recreational facilities include three tennis courts, a squash court, a bar and rooms for table tennis and television (fitted to receive Teletext broadcasts).

When the College is full, some courses are accommodated at Boundary Hall, Tadley, some 10 miles away and transported to and from the College by private coach. Teaching is always at the College but students on such courses may use the recreational facilities at both Shinfield Park and Boundary Hall.

Whilst most courses are designed for personnel of the Meteorological Office, when places are available they are open to students nominated by other meteorological services. Occasionally courses are devised and run entirely for members of other services. During the year a scheme for payment in advance was introduced. Enquiries concerning attendance at any of the courses at the College should be addressed to: The Principal, Meteorological Office College, Shinfield Park, near Reading, RG2 9AU.

The general pattern of courses has continued as in previous years and is summarized in Table XVII. The total number of students completing courses this year was 714, substantially more than in previous years. On the Scientific Officers' Course, for those with good honours degrees, usually in mathematics or physics, there were 19 students on the course which finished early in the year. The current course has 23 students, 18 from within the Meteorological Office, 3 from Malaysia, 1 from Hong Kong and 1 from Brunei. This course includes 7 women and 7 students with postgraduate research experience in universities. The Applied Meteorology Course is for new entrants with a degree or Higher National Certificate and for existing staff who are similarly qualified. The course which ended early in the year had 35 students, including one each from Belgium, Jordan and Turkey, while that which ran in the second half of 1979 had 32 students, including one each from Switzerland, Jersey and International Aeradio Limited. Students from this course go on to become support scientists or, after further training on the job, forecasters.

The other course concerned with basic training in forecasting is the Initial Forecasting Course. It, too, consisted of 32 students in 1979. In recent years there have been few Office staff on this course but this year there were 17. Ten other services were also represented. Two students from Ghana and one each

from the Sudan, Nepal and the Yemen took the course as an integral part of courses at the University of Reading for the MSc or the honours BSc degree in meteorology. The latter is a sandwich course which requires, as preliminary qualifications, GCE 'A' level passes in mathematics and physics. So that students may obtain both a good graduate qualification and real experience in meteorology, the course lasts from 3½ to 4 years and consists of alternating periods of academic work in the University and work experience in the Office. The work in the Office is usually in a forecasting unit though members of the staff of the Office also gain experience in one or more Headquarters Branches. This year no members of the Office joined the Sandwich Course but two graduated, one with First Class Honours.

After several years' experience forecasters normally return for a 7-week Advanced Forecasting Course. Most members of this course are Scientific Officers of the Meteorological Office in the field for promotion to Higher Scientific Officer; they are given an audition by the BBC. This year three courses were held for a total of 34 students from the Office and 11 from other services, including 3 in western Europe.

To implement the policy of providing refresher courses for Higher Scientific Officers at intervals of 5–10 years, four Extension Courses were run this year. On these 4-week courses students revise their knowledge of synoptic meteorology and bring it up to date. They are guided in the choice of a project which they undertake in order to help them later to conduct minor investigations into the weather in the areas for which they are responsible. An alternative course for Higher Scientific Officers is the Advanced Forecasting (Refresher) Course. This lasts three weeks and is essentially for revision and updating of the students' practice and knowledge of synoptic meteorology; one course was held this year.

An innovation for forecasting staff was a one-week Course in Defence Meteorology run at the Royal Air Force Staff College, Bracknell, by the Office in co-operation with senior officers of all three fighting services. Special emphasis was put on finding out and meeting the needs of various arms and on appropriate techniques of briefing. It is planned to run this course twice yearly in future, as an adjunct to First Courses for Forecasters.

Another innovation, for 21 staff at about the Principal Scientific Officer level, was a three-day residential seminar on the Management of Scientific and Technical Activities.

Assistant Scientific Officers who have newly joined the staff and are to work initially in support roles in Headquarters and in research teams at outstations attend a four-week course in Basic Meteorology. New ASOs who will work in forecasting and observing units, on the other hand, normally begin their training on an Initial Assistants' Course. On this four-week course they are taught the rudiments of plotting, coding and the making of observations. After it, as after all initial courses, training continues at the station. This on-the-job training forms an essential part of the scheme for assistants (and, indeed, for forecasters). After about three years, ASOs from forecasting and observing offices attend the Advanced Assistants' Course which lasts six weeks and provides training in basic meteorology, more advanced coding, communications, pilot-balloon work and elementary instrument maintenance. This year 11 initial courses, three basic and three advanced courses were held at the College. Because of the need to give new staff appropriate training as early in their working life as possible, the autumn was given over almost entirely to initial

courses and some planned advanced courses were postponed until the New Year. Last year's innovation for ASOs with long experience, the Extension Course for Assistants, was repeated.

During the year the Station Supervisors' Course was renamed the Scientific Officers (Supervisors) Course. This four-week course continues to serve as a refresher course and as a course for Scientific Officers newly promoted to fill supervisory posts. Two were held. Their purpose was akin to that of the three-week Senior Meteorologists' Course which, at a higher level, aims to give Senior Scientific Officer forecasters or support scientists a broad view of recent developments; one such course was run this year.

While the large number of new entrants into the science grades in the Office led to more people attending initial courses at all levels than for many years, separate courses continued to be run at the College for observers who man the Auxiliary Reporting and Climatological Stations in the UK, for Air Traffic Control staff who make weather observations at some aerodromes and for Senior Observers of the Saudi-Arabian Department of Meteorology. A College instructor gave four one-week courses in weather observing at HM Coastguard School at Brixham. Two initial courses for Meteorological Office staff who use the Office COSMOS computer system were also well attended. Both were followed by six to nine months' training on the job and then a two-week second course. A number of specialized lectures on these courses were given by members of the Data Processing Branch and one member of that Branch regularly acts as a full-time lecturer during the course. Other courses were held in Low Latitude Meteorology and Meteorological Statistics.

There has been less scope this year for outside organizations and other branches of the Office to use the College for meetings and conferences.

Staff joining the Meteorological Office as Assistant Scientific Officers are expected to improve their scientific qualifications by further study, usually at technical colleges and colleges of further education. The number of staff released for part-time study this year was 180. A further 54 members of staff are taking Open University or other Further Education courses with assistance under the Civil Service Further Education Scheme. In addition 18 staff began, or continued with, a block release course at the Reading College of Technology for the Higher National Certificate in mathematics, statistics and computing. This course consists of four six-week periods of full-time study, spread over two years. During these periods of full-time study staff live at Shinfield Park or at Boundary Hall. Thirteen members of the staff took their final examination this year, 11 were successful and 2 were referred in one subject. During the year 15 members of the staff were on Special Leave with Pay for full-time university studies or to attend sandwich courses. In addition, four are taking advantage of a scheme under which scientists can continue to work in the Office and study towards a PhD degree under the joint supervision of the Office and a co-operating university. Support was also given to four members of the Office to attend one-week Field Study Courses run by the Royal Meteorological Society.

Arrangements for this further study are co-ordinated by members of the directing staff of the College and by members of the personnel branch. Both groups have also kept abreast of developments in connection with the Technical Education Council's courses. In particular, the Office co-operated with the Reading College of Technology in devising a new block-release course in mathematics, statistics and physics under Technical Education Council and

Business Education Council auspices to replace the current HNC in mathematics, statistics and computing. Members of the Office serve on several relevant advisory bodies.

Table XVII shows the number of overseas students who have attended courses during the year at the Meteorological Office College and the School of Technical Training. Most were sponsored by their governments, by the World Meteorological Organization or by Overseas Development Aid. In addition 29 underwent practical training on the job in various branches of the Office; they came from 29 different countries and territories and gained experience in various areas of work including forecasting, communications, marine meteorology, climatology, numerical weather prediction and handling of meteorological data by computer.

General Activities of the Research Directorate

The Meteorological Office continued to work closely with a number of national and international bodies which are concerned with meteorological research. The Office provides representatives on a number of research-oriented committees of the Royal Society, the Natural Environment Research Council and the Science Research Council. In the international field, scientists from the Office serve on several working groups of the World Meteorological Organization and of the International Association of Meteorology and Atmospheric Physics.

The scientific research of the Office was reviewed by the Meteorological Research Committee and its subcommittees during the course of nine meetings. The Committee also advises on a number of small university research projects which are directly supported by the Meteorological Office; these number five in addition to four placed through the Gassiot Committee of the Royal Society.

During the year several members of university staffs worked in the Office as consultants for short periods; three scientists from overseas worked for longer periods, during which they were supported by their home institutions.

K. H. Stewart
Director of Research

STATISTICS OF THE RESEARCH DIRECTORATE

TABLE XVI — LIBRARY, ARCHIVES AND CARTOGRAPHIC SECTION

Library

Publications received:	
Daily weather reports	11 034
Books, journals etc.	7600
Slides and photographs	1254
Individual books, pamphlets, articles etc. classified and catalogued	9060
Publications lent (excluding internal 48-hour loans):	
Daily weather reports	12 488
Books, journals etc.	18 118
Slides and photographs	9703
Number of exchange agreements	1122
Number of pages translated by Library translator	660
Russian 327, German 194, French 129, Czech 10	
Number of pages translated by freelance translators	113
Swedish 36, French 30, Japanese 21, Russian 16, Spanish 8, Latin 2	

Archives

Number of loans	386

Cartographic Section

Number of diagrams, maps and charts completed during year	3759
Number of reprographic jobs during year	376

TABLE XVII — TRAINING

The following figures give details of courses completed during 1979 at the Meteorological Office training establishments at Shinfield Park and Beaufort Park.

	Number of courses	Length in weeks	Met. O. staff	Others	Total
Scientific Officers	1	23	12	7	19
Applied Meteorology ('78) Part II	1	9	25	2	27
Applied Meteorology ('79) (Prep)	1	3	11	0	11
Applied Meteorology ('79) Part I	1	11	28	4	32
Initial Forecasting	1	18	17	16	33
Advanced Forecasting	3	7	16	14	30
Advanced Forecasting (Refresher)	1	3	9	0	9
Extension Course	4	4	34	2	36
Senior Meteorologists	1	3	12	0	12
Meteorological Statistics	2	4	17	1	18
Tropical Meteorology	1	3	0	12	12
Mediterranean Meteorology	1	3	0	6	6
Initial Programmers	2	4	28	0	28
Second Programmers	2	2	29	0	29
Basic Assistants	3	4	35	0	35
Initial Assistants	11	4	131	2	133
Advanced Assistants	3	6	29	4	33
Extension Assistants	2	4	18	0	18
SO (Supervisors)	2	4	18	0	18
Auxiliary and Co-operating Observers	5	1	0	71	71
Air Traffic Control Staff	4	1	0	47	47
Defence Meteorology Course	1	1	14	0	14
Saudi Arabian Observers	1	8	0	11	11

TABLE XVII (*continued*)

	Number of courses	Length in weeks	Met. O. staff	Others	Total
Management of Scientific and Technical Activities	1	3/5	21	0	21
ASO Pre Tech	1	3	4	1	5
*ASO/RMT Electronics	1	18	9	2	11
ASO/RMT Conversion	1	14	9	2	11
Radiosonde Mk 3 Ground Equipment ...	3	2	15	0	15
Met. Office Data Logging Equipment ...	2	2	10	0	10
Digital Anemograph Logging Equipment	2	2	8	0	8
Radar type WF3	1	3	2	0	2
Satellite Facsimile Recording Equipment	1	1	6	0	6
Grawsonde	2	1	2	0	2
Astor Sonde	1	3	1	0	1
Vaisala Sonde	1	3	1	0	1
Grawsonde Conversion	1	10	0	13	13
Totals			571	217	788

*Course carried for Meteorological Office by RAF Support Command at RAF Sealand

Students from the following territories attended courses which terminated during 1979.

	Number of students
Afghanistan	1
Bahrain	6
Bangladesh	1
Belgium	4
Brunei	1
Cyprus	2
Dubai	1
Ecuador	1
Ethiopia	2
Germany (Federal Republic)	1
Ghana	3
Guernsey	1
Hong Kong	7
Isle of Man	1
Jersey	2
Jordan	2
Malaysia	7
Nepal	1
Qatar	3
Saudi Arabia	12
Seychelles	1
Sudan	1
Switzerland	3
Syria	2
Tanzania	1
Territories served by International Aeradio Ltd	4
Yemen	1
Zambia	1
Total	73

ADMINISTRATION

Personnel Management

Introduction

Meteorological Office staff serve at over 100 locations in the United Kingdom and overseas. Numbers of staff at each location range from about 1200 in the Headquarters at Bracknell down to single individuals at a few isolated units. This poses a number of management problems very different from those in many other areas of the Civil Service. Personnel management for the majority of staff, including all those in the scientific and technical grades, is undertaken centrally by the Secretary of the Meteorological Office and, under him, the Assistant Director and staff of the Personnel Management Branch at Bracknell. In this way the career prospects of staff and the opportunities open to them do not depend on the size or location of their particular unit. At the same time the Office has maximum flexibility in meeting its varied staff requirements. Some aspects of the personnel management work are outlined in the following paragraphs.

Manning

Movements of most members of the staff are the responsibility of the manning sections at Bracknell, but short-period detachments may be arranged by Principal Meteorological Officers at outstations. The majority of posts at outstations and a substantial number at Headquarters have to be manned for 24 hours a day, 7 days a week, and this requires considerable planning and a high degree of staff mobility. During 1979 the number of postings averaged about 20 a week. Prior consultations with line managers and the career development section help to ensure, as far as possible, that long-term needs and preferences of the individuals are taken into account, as well as the meeting of short-term requirements.

Career development

Career development panels continued to monitor and guide the careers of staff members for whom they are responsible. In addition to the two main panels for senior and high-potential specialist staff, separate panels within the Personnel Branch have continued to help with the career development of others. Considerable importance is attached to the successful operation of the staff appraisal system, and high priority was given in 1979 to training staff in the skills of staff reporting and appraisal interviewing. Training was given from resources within the section, and a total of 238 staff were given training.

During 1979 increasing attention was paid to the training needs of all staff and to the development of a planned schedule of professional and management training as an essential part of career development and planning. This led to a further improvement of the system of recording training and career histories, based upon the MOD Civilian Personnel Management Information System (CIPMIS), together with the establishment of a Training Officer, tasked with the co-ordination of staff training nominations and liaison on training matters with line managers in branches and outstations.

Records

Personal records of the majority of staff members are held centrally in the records section which is responsible for maintaining up-to-date information on the CIPMIS system. Secretarial work for the various promotion boards in the Meteorological Office is carried out by the records staff, working in co-operation with the career development and manning sections. Some functions, such as approval of special leave, are delegated to Principal Meteorological Officers and other line managers. However, all questions on conditions of service and general administration, together with discipline etc., are handled through the records section.

Manpower planning

Continuous monitoring and planning is required to ensure an efficient level of manning in the Office within the agreed overall complement. Statistics of staff numbers, promotion patterns, recruitment and wastage, are closely co-ordinated, and the information is used as the basis for manpower-planning exercises carried out using computer programs developed by the Civil Service Department. Interpretation of the results has an immediate use for recruiting purposes, and, in the longer term, gives indications of likely requirements for training. The system is well suited to the closely knit centrally managed Meteorological Office and can be used to test the effects of possible changes on the future career prospects of staff members and on future recruiting requirements.

Recruitment

The Personnel Branch is responsible for recruitment, in accordance with regulations laid down by the Civil Service Commission, to most grades for which the Office has a requirement, although recruitment of graduates is undertaken as part of the Commission's centralized recruiting program.

A great deal of effort was put into the recruiting of scientists with the result that 50 graduates entered the Office against a target of 55. At the Assistant Scientific Officer level, also, a reasonable degree of success was achieved with 137 entrants compared to a target of 150. These excellent results reflect greatly on all those who took part in the exercise especially as there was some considerable uncertainty regarding the outcome of Civil Service Science Group pay negotiations during the recruiting period as well as fierce competition from employers in the private and public sectors.

In addition to the scientists mentioned above, other staff joining the Office during the year included 4 in the Professional and Technology Officer grades as a result of Civil Service trawls, 11 Clerical Assistants and 16 Data Processors from Open Competitions. Temporary staff included 6 college-based sandwich course students undergoing industrial training and 7 vacation students who were employed for about two months in the summer. The Office also co-operated in one-week Work Experience schemes, with Bracknell College and a school in Camberley.

Staff numbers

At the end of 1979 the total number of posts of all grades was 3208, a decrease of 57 over the year. The actual strength at the end of the year was made up as follows:

Deputy Secretary	1
Under Secretary	2
Science Group	
Chief Scientific Officer	1
Deputy Chief Scientific Officer	6
Senior Principal Scientific Officer	26
Principal Scientific Officer	113
Senior Scientific Officer	283
Higher Scientific Officer	530
Scientific Officer	481
Assistant Scientific Officer	895
Administration Group	
Assistant Secretary	1
Principal	1
Executive grades	34
Clerical grades	135
Marine Staff	
Marine Superintendent	1
Nautical Officer grades	13
Ocean Weather Ships and Base	
Officers and non-industrial grades	46
Crew and industrial grades	44
Professional Engineering Staff	
Principal Professional and Technology Officer	1
Professional and Technology Officer Grade I	3
Professional and Technology Officer Grade II	7
Professional and Technology Officer Grade III	5
Professional and Technology Officer Grade IV	4
Technical and Signals grades	275
Typing and miscellaneous non-industrial grades	127
Industrial employees	93
Locally entered staff and employees overseas	51

Finance

Except for the common services provided by other government departments as part of their normal functions (i.e. accommodation by the Property Services Agency of the Department of the Environment, and stationery and office machinery by Her Majesty's Stationery Office) the cost of the Meteorological Office is borne by Defence Votes.

The tables which follow give the operating expenses of the component parts of the Meteorological Office: the cost of carrying out major functions—forecasting, collecting observations, etc., and the income receivable from repayment services, all for the financial year 1978/79.

FINAL STATEMENT OF OPERATING EXPENSES BY METEOROLOGICAL OFFICE FUNCTIONS FOR THE YEAR ENDED 31 MARCH 1979

	£000	£000
Main functions		
1. Making and handling observations	7694	
2. Forecasting	7237	
3. Meteorological (including climatological) advice	3508	
4. Research and development	5828	
		24 267
Supporting functions		
5. Administration	1983	
6. Technical support	3148	
7. International activities	1186	
8. Computer services	2053	
9. Telecommunications	3980	
		12 350
		36 617

FINAL METEOROLOGICAL OFFICE RECEIPTS 1978/79 (CASH RECEIVABLE)

(1)	(2) £000	(3) £000	(4) £000
SERVICES TO:			
Ministry of Agriculture, Fisheries and Food			105
Other Exchequer Departments (Department of the Environment etc.)			47
Civil Aviation Authority			9665
Natural Environment Research Council			31
Other non-Exchequer Departments			27
			9875
Meteorological Office College – Training of meteorologists... ...			95
Secondments to outside bodies			87
Comprehensive forecasting service for the offshore oil industry ...		416	
Forecasting service developed to meet individual user's special needs:			
Ship-routeing Service	29		
Gas Boards	90		
Central Electricity Generating Board	59		
British Rail	8		
Independent Broadcasting Authority	16		
British Broadcasting Corporation	24		
Press	15		
Other customers' special services	34		
		275	
Automatic Telephone Weather Service (Post Office)		189	
Issue of forecasts by prior arrangement	6		
Issue of local detailed forecasts by prior arrangement	4		
Issue of forecasts up to 24 hours in advance	56		
Issue of expected occurrences of specified weather (Frost, Fog etc.)	48		
Pigeon-racing forecasts	7		
Issue of three-day dry-spell forecasts	6		
Issue of road-danger warnings	28		
Issue of weekend temperature forecasts	4		
Investigations and other professional work as required	82		
Preparation of Weekly, Monthly and Annual Weather Summaries	12		
Preparation of Certified Statements	16		
Outside attendances by professional staff (Court appearances) ...	2		
Supply of copies of data/records	56		
Daily Weather Reports/Publications/Met. Forms ...	7		
Other services	16		
		350	
			1230
			£11 287

FINAL STATEMENT OF OPERATING EXPENSES OF THE METEOROLOGICAL

(1) Expenditure	(2) Offices at RAF stations	(3) Offices at CAA/ATCC stations
	£000	£000
1. Personnel (pay, allowances, ERNIC and Superannuation) ...	5101	3134
2. Materials (stores, minor equipment, maintenance, ships' expenses, etc.)	275	161
3. Staff travel and subsistence	123	60
4. Accommodation (DOE—agency basis)	560	
5. Office support (HMSO—agency basis) (stationery, office machines etc.)	51	36
6. Telecommunications		
7. Equipment support (aircraft and motor transport)	90	
	6200	3391
8. North Atlantic Ocean Stations (NAOS) operating cost receipts		
9. Grants and subscriptions:		
Research Grants		
Grants to World Met. Organization		
Subs to World Met. Organization		
World Weather Watch upper-air stations Overseas ...		
Subs to ECMWF		
Training expenses of Voluntary Co-operation Program of World Met. Organization		
European Space Agency Meteosat Program		
First GARP Global Experiment contribution (FGGE) ...		
European Network of Ocean Stations (ENOS)		
Co-operative Automatic Weather Radar		
North Atlantic Ocean Stations (NAOS) contribution ...		
10. Other expenditure:		
Payment to auxiliary observers		
	6200	3391
11. Depreciation (Historical):		
Equipment	47	23
Computers		
Ships		
Aircraft		
	6247	3414

*Operating expenses of research outstations have been included in column 7.

OFFICE FOR THE YEAR ENDED 31 MARCH 1979

(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Other met.	Met. Office HQ Directorates				
Weather centres	services outstations*	Met. Services	Research*	Admin.	1978/79 Total	1977/78 Total
£000	£000	£000	£000	£000	£000	£000
1079	3051	5971	3046	1539	22 921	21 302
55	1556	813	695	98	3653	3609
21	63	102	57	30	456	510
128	223	825	617	309	2662	2586
13	33	61	34	46	274	228
		1123			1123	955
	35	20	894	47	1086	712
1296	4961	8915	5343	2069	32 175	29 902
	(1854)				(1854)	(1636)
			33		33	30
		123			123	74
		393			393	372
		182			182	161
		576			576	452
		41			41	41
		1269			1269	—
		17			17	17
		1			1	—
		41			41	8
		1779			1779	1364
		71			71	63
1296	3107	13 408	5376	2069	34 847	30 848
7	161	105	98	1	442	432
		575	9		584	572
	492				492	492
			252		252	252
1303	3760	14 088	5735	2070	36 617	32 596

F. R. HOWELL
Secretary
Meteorological Office

INTERNATIONAL CO-OPERATION

The major event of the year was the Eighth World Meteorological Congress which was held in Geneva between 30 April and 25 May. Eighth Congress was chiefly notable for the creation of a major new program, the World Climate Program (WCP). The WCP will entail the co-ordination of the activities of Members to monitor and study the Climate of the Earth and its long term trends and shorter-period fluctuations; it may last for a decade or more and entail work in many branches of meteorology especially in numerical modelling of the atmosphere. There was also an unusually detailed discussion of the Program of the Organization, in which the United Kingdom played a leading part, which resulted in a substantial reduction in the proposed Budget despite the new activities approved.

The Congress was followed by the 31st Session of the WMO Executive Committee which sat between 28 May and 1 June. Congress decided to increase the elected membership of the Committee to 19 bringing the total membership to 29. Members of the Committee are elected by Congress as individuals and represent the Members of WMO rather than their Governments. The Director-General was elected to the Committee which was chaired by Dr R. L. Kintanar of the Philippines who succeeded Mr M. F. Taha of Egypt as President of WMO.

The only other constituent body of WMO to meet during the year was the Commission for Agrometeorology which convened in Sofia, Bulgaria between 17 and 28 September. Mr C. V. Smith, Assistant Director (Agriculture and Hydrometeorology) led the United Kingdom delegation.

The Council of the European Centre for Medium Range Weather Forecasts met at Reading in June and November; The Council on which the Director-General represents the United Kingdom is the governing body for the Centre. During the June meeting His Royal Highness The Prince of Wales opened the new headquarters building of the ECMWF in the presence of Ambassadors of the 17 Member States, Members of Council and distinguished visitors. The building, which is adjacent to the Meteorological Office College at Shinfield Park, has been provided by the United Kingdom. It was designed by staff of the Property Services Agency and has attracted favourable comment. During the November meeting Mr P. K. Rohan of Ireland was elected President of the Council in succession to Dr L. A. Vuorela of Finland; the retiring Director of the Centre took the opportunity to pay generous tribute to the Office and to other UK Government departments for the constructive co-operation he had received during his period of appointment.

The Council has three advisory groups—the Finance Committee, the Scientific Advisory Committee and the Technical Advisory Committee. The United Kingdom provides members for all three; Mr F. H. Bushby, Director of Services, is a member of the Scientific Advisory Committee, Dr R. L. Wiley, Assistant Director (Systems Development) of the Technical Advisory Committee and Mr G. J. Day, Assistant Director (International and Planning) sits on the Finance Committee with representatives of the Personnel Management and Finance Branches of the Ministry of Defence.

Work on projects within the European Co-operation in Science and Technology (COST) continued during the year. The Office is active in COST Project

43 (Oceanography and Meteorology) in which Dr D. N. Axford, Assistant Director (Operational Instrumentation) is Chairman of the Management Committee and Dr R. E. W. Pettifer (Met O 16) is a member of a Regional Sub-Group planning ocean data buoy networks. In COST Project 72 (Meteorology) the Office has been active in promoting a new project concerned with the co-ordination within Europe of rainfall measurements by radar. Mr G. A. Clift (Met O 16), as a Member of the Technical Committee for COST 72, has been much concerned with the drafting of a Memorandum of Understanding for the new project.

The year 1979 was the year of the First GARP Global Experiment (FGGE), probably the greatest international scientific experiment ever undertaken. An object of FGGE is to assemble a unique data set on which many important researches in the years ahead will be based. The United Kingdom has been involved in the Experiment in several ways and Dr N. E. Rider, Deputy Director (Observational Services) is a member of the WMO Executive Committee Intergovernmental Panel for FGGE. For the first six months of the year Mr G. A. Corby, formerly Director of Services, was employed as a consultant in the WMO/ICSU GARP Activities Office in Geneva which co-ordinated the Experiment. The United Kingdom had special responsibility in the Experiment for assembling the data from Europe and Africa and the adjacent oceans for transmission in an agreed format to the World Data Centres.

The International Union of Geodesy and Geophysics (IUGG) held its 17th General Assembly in Canberra, Australia in December. The Assembly was attended by Mr F. H. Bushby, Director of Services, Mr P. Goldsmith, Deputy Director (Physical Research), Dr R. Hide (Met O 21) and Dr K. A. Browning (Met O RRL, Malvern). Mr Bushby also attended the concurrent meeting of the WMO/ICSU Joint Organizing Committee Working Group on Numerical Experimentation (WGNE) which was held in Melbourne.

In March the Director-General attended the 9th Informal Conference of Directors of European Meteorological Services in Bordeaux. These meetings are held annually prior to a WMO Congress or Executive Committee and afford an opportunity for an exchange of views on important topics.

Throughout the year members of the Office have been active in various bodies of the European Space Agency, a particular interest being the operation of the European geostationary satellite Meteosat. Dr K. H. Stewart, Director of Research, is a member of the ESA Meteorological Satellite Program Board and Mr A. I. Johnson (Met O 19) sits on the Meteosat Operations Advisory Board.

Other WMO meetings or joint WMO meetings with other international bodies, in which Meteorological Office staff took part, were as follows:

Subject	*Place and date*	*Attended by*
NAOS—Meeting of Telecommunication Experts	Shinfield Park January	Dr N. E. Rider, Deputy Director (Observational Services) Mr D. McNaughton, Assistant Director (Telecommunications) Captain G. A. White, Marine Superintendent Mr C. V. Else (Met O 5) Mr W. A. Stonham (Met O 5)

Subject	*Place and date*	*Attended by*
CBS – Informal Planning Meeting on Integrated Observing System Study over the Ocean	Geneva January/February	Dr N. E. Rider, Deputy Director (Observational Services) Dr W. H. Lyne (Met O 11)
World Climate Conference	Geneva February	Sir John Mason, Director-General Mr A. Gilchrist, Deputy Director (Dynamical Research) Mr D. E. Parker (Met O 13) Dr N. Thompson (Met O 8)
World-wide Symposium on Education and Training in Meteorology	Madrid March	Mr S. G. Cornford, Assistant Director (Professional Training)
Third meeting of the FGGE Working Group on Data Management	Paris April	Mr M. V. Jones (Met O 22)
Eighth Congress	Geneva April/May	Sir John Mason, Director-General Mr G. J. Day, Assistant Director (International and Planning) Mr A. C. Hughes, Secretary, Meteorological Office Mr D. J. Clark (Met O 17)
Executive Committee – Thirty-first Session	Geneva May/June	Sir John Mason, Director-General Mr G. J. Day, Assistant Director (International and Planning)
NAOS Board – Fourth Session	Geneva June	Dr N. E. Rider, Deputy Director (Observational Services)
Meeting of Experts on Stratospheric Circulation Analysis and Ozone	Washington July	Dr D. R. Pick (Met O 19)
JOC Working Group on Land Surface Processes	Geneva July	Dr D. J. Carson (Met O 20)
Impact of GATE on Large-Scale Numerical Modelling	Massachusetts August	Mr A. Gilchrist, Deputy Director (Dynamical Research)
CAgM – Seventh Session	Sofia September	Mr C. V. Smith, Assistant Director (Agriculture and Hydrometeorology) Mr W. R. Sparks (Met O 8)
WMO/IOC Informal Planning Meeting on Marine Environmental Data Management	Geneva September	Mr D. J. Painting (Met O 3)
ESA/WMO/SMF Technical Conference on the Use of Data from Meteorological Satellites	Trégastel, France September	Mr D. E. Miller, Assistant Director (High Atmosphere) Mr J. R. Eyre (Met O 19) Mr R. S. Bell (Met O 2) Mr S. G. Smith (Met O 3)
PEP Panel/CAS Working Group – Ninth Session	Geneva September	Mr P. Goldsmith, Deputy Director (Physical Research)
Symposium on the Long-range Transport of Pollutants	Sofia October	Dr F. B. Smith (Met O 14)
RA VI Working Group on Meteorological Telecommunications	Geneva October	Mr D. McNaughton, Assistant Director (Telecommunications)
Informal Planning Meeting on Integrated WWW Study System	Geneva October	Mr D. R. Grant, Assistant Director (Observational Requirements and Practices)
Symposium/Workshop on Digital Radar Reflectivity Processing with Applications to Hydrometeorology	Edmonton, Canada October	Mr C. G. Collier (Met O RRL)
Extraordinary Meeting of the FGGE Working Group on Data Management	Norrköping, Sweden October	Mr M. V. Jones (Met O 22)
CMM *ad hoc* Study Group on Marine Climatology	Geneva October/November	Mr D. J. Painting (Met O 3)

Subject	Place and date	Attended by
CAeM Technical Conference on Aviation Meteorology	Geneva November	Mr R. J. Ogden, Assistant Director (Public Services) Mr M. J. O. Dutton (Met O 9)
Planning Meeting of CAeM Working Group on Provision of Meteorological Information Required before and during Flight	Geneva November	Mr P. D. Borrett (Met O 7)
FGGE – Seventh Session of EC Intergovernmental Panel	Geneva November	Dr N. E. Rider, Deputy Director (Observational Services)
NAOS Working Group on the Future of NAOS after 1981	Geneva December	Dr N. E. Rider, Deputy Director (Observational Services) Captain G. A. White, Marine Superintendent
Informal Planning Meeting on New Observing Systems	Geneva December	Dr D. N. Axford, Assistant Director (Operational Instrumentation)
Study Group on the Guide to the GDPS	Geneva December	Miss M. J. Atkins (Met O 2)

Attendances not already listed, at international conferences sponsored wholly or primarily by bodies other than WMO, and other visits abroad, were as follows:

Subject	*Place and date*	*Attended by*
ECMWF Finance Committee – 17th Session	Shinfield Park January	Mr G. J. Day, Assistant Director (International and Planning)
Visit to University College for discussions on collaborative work on soliton theory	Dublin January	Dr I. N. James (Met O 21)
NATO CDC Group of Experts on Fall-out Warning Exercises	Rome January	Mr P. G. Rackliff (Met O 6)
Installation of Dobson Ozone Spectrophotometer	Singapore January	Mr J. H. Convery (Met O 19)
ESA Meteosat Operations Advisory Group	Darmstadt January	Mr A. I. Johnson (Met O 19)
European Meteorological Services Working Group Meeting on Possible Future European Meteorological Satellites	Zurich January	Mr P. Goldsmith, Deputy Director (Physical Research)
First Meeting of Basic Operational Requirements Working Group (BORMET) of the Meteorological Advisory Group (METAG) to the European Air Navigation Planning Group of ICAO	Paris January	Mr P. D. Borrett (Met O 7)
ESA – Meteorological Services Working Group on Continuation of Meteosat Program	Zurich January	Mr P. Goldsmith, Deputy Director (Physical Research) Mr D. E. Miller, Assistant Director (High Atmosphere)
TIROS-N Stratospheric Sounding Unit – Integration and Test Program	Princetown, N.J./ Washington, D.C. January	Dr J. Nash (Met O 19)
Seventeenth Session of JOC Working Group on Numerical Experimentation	Cambridge February	Mr F. H. Bushby, Director of Services
Third Meeting of the ICAO Working Group on Meteorological Services for International General Aviation	Paris February	Mr K. Bryant (Met O 7)

Subject	*Place and date*	*Attended by*
ESA Meteosat Operations Advisory Group	Darmstadt February	Mr A. I. Johnson (Met O 19)
NATO MCMG Sub-group VII	Fürstenfeldbruck February	Mr J. G. Moore (Met O 2)
Central Region Meteorological Training Program Project Officers	Maastricht February	Mr K. Pollard (Met O 6)
NATO MCMG and Working Groups—Chairmen's Liaison Meeting	Brussels/Bonn/Hilversum February	Mr I. J. W. Pothecary, Assistant Director (Defence Services)
ESA Meteorological Satellite Program Board	Paris February	Dr K. H. Stewart, Director of Research Mr J. W. Grant, Head of Met O 4
Eurocontrol	Paris March	Dr D. A. Forrester (Met O 2)
NATO MCMG Working Group WP/WC	Oslo March	Mr C. E. Goodison (Met O 5)
COST Project 43—Management Committee Meeting	Brussels March	Dr D. N. Axford, Assistant Director (Operational Instrumentation)
COST Project 43—Regional Sub-Group Meeting	Brussels March	Dr R. E. W. Pettifer (Met O 16)
ARGOS Data Processing and Utilization	Toulouse March	Mr R. G. Flavell (Met O 16)
ESA Meteorological Satellite Program Board	Paris March	Mr J. W. Grant, Head of Met O 4
Second ATOC Sub-Group	2 Weather Wing Kapaun, West Germany March	Mr J. F. Keers (Met O 6)
Visit to NASA Langley Research Center	Langley, Va March	Dr A. O'Neill (Met O 20)
Thirty-second Meeting of the Irish National Committee for Geodesy and Geophysics	Dublin March	Mr E. Cayhill (Met O 7)
Second Meeting of BORMET	Paris March	Mr P. D. Borrett (Met O 7)
Technical Advisory Group of the Oceanographic Committee of UKOOA	Paris March	Mr R. M. Morris (Met O 7)
Supervision of Benchmark programs re procurement of a powerful scientific processor for attachment to COSMOS	Minneapolis, Minn. March	Dr R. L. Wiley, Assistant Director (Systems Development)
Ninth Informal Conference of Directors of European Meteorological Services	Bordeaux March	Sir John Mason, Director-General
NATO MCMG—Forty-ninth Working Group and Sub-group II	Oslo March/April	Mr D. W. Tann (Met O 6) Mr C. E. Goodison (Met O 5)
ECMWF Finance Committee—18th Session	Shinfield Park April	Mr G. J. Day, Assistant Director (International and Planning)
ESA Meteorological Satellite Program Board	Paris April	Mr J. W. Grant, Head of Met O 4
British Theoretical Mechanics Colloquium	Bath April	Dr I. N. James (Met O 21)
Euromech Meeting—Airflow over Hills and Mountains	Munich April	Dr P. R. Jonas (Met O 21) Mr T. S. Hills (Met O 20) Dr R. I. Sykes (Met O 14) Dr P. W. White (Met O 11)
COST Project 72 Technical Committee on Meteorological Instrumentation	Brussels April	Mr G. A. Clift (Met O 16)

Subject	Place and date	Attended by
Institute of Physics (Irish Branch) and lectures at universities	Cork/Dublin April	Sir John Mason, Director-General
Visit to Atmospheric Physics Department, University of Washington	Seattle, Wash. April	Dr A. O'Neill (Met O 20)
EEC Solar Energy R & D Action 4 Project F	Valbonne, France April	Mr H. E. Painter (Met O 1)
Third Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems	Tennessee April	Dr W. T. Roach, Assistant Director (Special Investigations)
Twenty-seventh AFCENT Meteorological Committee	Lahr, West Germany April	Mr J. F. Keers (Met O 6) Mr K. Pollard (Met O 6)
ESA Meteosat Operations Advisory Group	Darmstadt April	Mr A. I. Johnson (Met O 19)
ESA Meteosat Scientific and Technical Advisory Group	Lannion, France April	Mr D. E. Miller, Assistant Director (High Atmosphere)
Third Meeting of BORMET	Paris May	Mr P. D. Borrett (Met O 7)
ESA Meteorological Satellite Program Board	Paris May	Dr K. H. Stewart, Director of Research
Eurocontrol	Bracknell May	Dr D. A. Forrester (Met O 2)
Discussion on processing and subsequent scientific analysis of the aircraft and ship data gathered during JASIN, 1978	Massachusetts May	Dr C. J. Readings (MRF) Mr S. Nicholls (MRF) Dr G. J. Jenkins (Met O 14)
Conference on Ocean Hydrodynamics	Liège May	Dr J. F. B. Mitchell (Met O 20)
International Symposium on Sulphur Emissions and the Environment	London May	Dr F. B. Smith (Met O 14)
ESA Meteosat Operations Advisory Group	Darmstadt May	Mr A. I. Johnson (Met O 19)
TIROS-N Stratospheric Sounding Unit — Final testing of NOAA-A, Western Test Range	USA May	Dr J. Nash (Met O 19)
Discussion on chemi-luminescent ozonesonde	Toulouse/Paris May	Dr E. L. Simmons (Met O 19)
Visit to NMC, GDFL, Canadian Meteorological Centre	Washington/ Princeton/Montreal June	Mr R. Kershaw (Met O 2)
ESA Meteosat Scientific Users Meeting	Darmstadt June	Mr P. Goldsmith, Deputy Director (Physical Research)
Visit to NCAR — Collaborative project with Florida State University, Geophysical Fluid Dynamics Institute	Boulder, Col. June	Dr I. N. James (Met O 21)
Conference on Comparative Fluid Dynamics	Annapolis, Md June	Dr R. Hide (Head of Met O 21)
COST Project 43 Regional Sub-group Meeting	London June	Dr R. E. W. Pettifer (Met O 16) Mr M. J. Kerley (Met O 16)
ECMWF Council	Shinfield Park June	Sir John Mason, Director-General Mr G. J. Day, Assistant Director (International and Planning)
Solar Radiation Data Acquisition Group of EEC Solar Energy Program	Valentia June	Mr B. R. May (Met O 1)
Third ATOC Sub-group	Traben-Trarbach, West Germany June	Mr J. F. Keers (Met O 6)

Subject	*Place and date*	*Attended by*
NATO Thirty-sixth MCMG	Brussels June	Mr I. J. W. Pothecary, Assistant Director (Defence Services) Mr D. W. Tann (Met O 6)
TIROS-N Stratospheric Sounding Unit — Participation in the integration and test program	Princeton, N.J./ Washington, D.C. June	Dr J. L. Brownscombe (Met O 19) Mr B. Tonkinson (Met O 19)
ECMWF Finance Committee — 19th Session	Shinfield Park July	Mr G. J. Day, Assistant Director (International and Planning)
Second Symposium on Turbulent Shear Flows	London July	Dr P. J. Mason (Met O 14) Dr R. I. Sykes (Met O 14)
International Conference on Climate and History	Norwich July	Mr D. M. Houghton, Assistant Director (Synoptic Climatology) Mr D. E. Parker (Met O 13) Mr D. Warrilow (Met O 8) Mr G. H. Ross (Met O 3)
Fifth International Conference on Wind Engineering	Colorado July	Mr R. H. Collingbourne (Met O 3)
Twenty-second Session of Sub-Committee on Safety of Fishing Vessels convened by the Intergovernmental Maritime Consultative Organization	London July	Captain G. H. White, Marine Superintendent
COST Project 43 Management Committee	Brussels July	Dr D. N. Axford, Assistant Director (Operational Instrumentation) Dr R. E. W. Pettifer (Met O 16)
NATO Twenty-first SHAPE Meteorological Committee	Ramstein, West Germany July	Mr D. W. Tann (Met O 6) Dr J. I. Gibbs (Met O 6)
TIROS-N Stratospheric Sounding Unit — Participation in the integration and test program	Princeton, N.J./ Washington, D.C. July	Dr J. Nash (Met O 19)
TIROS-N Stratospheric Sounding Unit — Processing of stratospheric data	Washington, D.C. July	Dr D. R. Pick (Met O 19) Mr J. S. Campbell (Met O 19)
Conference of the Commission on Atmospheric Chemistry and Global Pollution	Boulder, Col. August	Mr P. Goldsmith, Deputy Director (Physical Research) Mr K. S. Groves (Met O 15)
COST Project 43 Regional Sub-group Meeting	Ireland August	Dr R. E. W. Pettifer (Met O 16)
	Bergen, Norway September	Dr R. E. W. Pettifer (Met O 16)
ECMWF Finance Committee — 20th Session	Shinfield Park September	Mr G. J. Day, Assistant Director (International and Planning)
NATO Army Armaments Group AC/225 Panel XII	Brussels September	Mr P. G. Rackliff (Met O 6)
Technical Conference on the Use of Data from Meteorological Satellites	Trégastel, France September	Mr S. G. Smith (Met O 3)
Eighth International Biometeorological Congress	Shefayim, Israel September	Dr J. R. Starr (Met O 8)
The Hercules Aircraft was detached to Dakar	Dakar September	A team including scientists from Met. Research Flight and the Cloud Physics Branch
EEC Solar Energy Program Project F	Brussels September	Mr B. R. May (Met O 1)
ESA Meteosat Operations Advisory Group	Darmstadt September	Mr A. I. Johnson (Met O 19)
ESA Meteosat Scientific and Technical Advisory Group	Toulouse September	Mr D. E. Miller, Assistant Director (High Atmosphere)

Subject	Place and date	Attended by
First Session of ECMWF Technical Advisory Committee	Shinfield Park September	Dr R. L. Wiley, Assistant Director (Systems Development) Mr D. E. Jones, Assistant Director (Central Forecasting)
Carrying out of tests on new plotting equipment at Benson SA	Paris September	Mr M. V. Jones (Met O 22)
Third Meeting of METAG	Paris September	Mr P. D. Borrett (Met O 7)
ECMWF – Dynamical Meteorology and Numerical Weather Prediction	Shinfield Park September	Mr R. Kershaw (Met O 2)
NATO MCMG – Sub-group VII	HQ SHAPE October	Mr J. G. Moore (Met O 2)
Oil Industry International Exploration and Production Forum and associated International Conference on Sea Climatology	Paris October	Mr R. M. Morris (Met O 7) Mr D. J. Painting (Met O 3)
ESA Meteosat Operations Advisory Group	Darmstadt October	Mr A. I. Johnson (Met O 19)
International Energy Agency – Solar Heating and Cooling Program	Copenhagen October	Mr B. R. May (Met O 1)
NATO MCMG Fiftieth Working Group	The Hague October	Dr J. I. Gibbs (Met O 6) Mr C. E. Goodison (Met O 5)
Fourth ATOC Sub-group	JHQ Rheindahlen October	Mr J. F. Keers (Met O 6)
European Advisory Panel on Meso-meteorology	Traben-Trarbach, West Germany October	Mr J. F. Keers (Met O 6)
Forty-first Session of Maritime Safety Committee of the Inter-Governmental Maritime Consultative Organization	London October	Captain G. A. White, Marine Superintendent
Visit to NATO Advanced Study Institute on Atmospheric Ozone	Aldeia das Acoteias, Portugal October	Dr A. O'Neill (Met O 20) Mr J. Austin (Met O 20)
Visit to General Fluid Dynamics Laboratory	Princeton, N.J. October	Dr J. F. B. Mitchell (Met O 20)
ESA Meteorological Satellite Program Board	Paris October	Dr K. H. Stewart, Director of Research
Working Meeting on the Evaluation of Models for Wind Turbine Generator Siting	Seattle, Wash. October	Dr K. M. Carpenter (Met O 11)
US Army Meso-Met Advisory Panel	Traben-Trarbach, West Germany October	Dr P. W. White (Met O 11)
Fourth Conference on Numerical Weather Prediction	Washington, D.C. October	Dr W. H. Lyne (Met O 11) Dr T. Davies (Met O 11)
International Conference on Water Resources	London October	Sir John Mason, Director-General
Visit and Lecture tour to University of Toronto and Canadian Meteorological Service	Toronto October	Sir John Mason, Director-General
First Meeting of Working Group for Methods of Application (Meteorology) (MAPMET) of METAG	Paris November	Mr P. D. Borrett (Met O 7)
Eleventh Regular Session of the Assembly of the Inter-Governmental Maritime Consultative Organization	London November	Captain G. A. White, Marine Superintendent
ECMWF Council	Shinfield Park November	Sir John Mason, Director-General Mr G. J. Day, Assistant Director (International and Planning)

Subject	*Place and date*	*Attended by*
IIASA Council	Vienna November	Sir John Mason, Director-General
ESA Climatology, Hydrology, Atmospheric Research and Meteorology (CHARM) Workshop	Ajaccio, Corsica November	Dr K. H. Stewart, Director of Research
ESA Meteorological Satellite Program Board	Paris December	Dr K. H. Stewart, Director of Research
NATO CDC Group of Experts on Fallout Warning Exercises	Copenhagen December	Mr P. G. Rackliff (Met O 6)
XVII General Assembly of the International Union of Geodesy and Geophysics (IUGG)	Canberra December	Mr F. H. Bushby, Director of Services Mr P. Goldsmith, Deputy Director (Physical Research) Dr R. Hide (Met O 21) Dr K. A. Browning (Met O RRL)
Eighteenth Session of JOC Working Group on Numerical Experimentation	Melbourne December	Mr F. H. Bushby, Director of Services
COST Project 43 Management Committee	Brussels December	Dr D. N. Axford, Assistant Director (Operational Instrumentation)
ESA Meteosat Operations Advisory Group	Darmstadt December	Mr A. I. Johnson (Met O 19)

The following staff were released by the Office during 1979 for service with international and other organizations:

Mr R. W. Lunnon	SSO	European Space Agency
Mr G. C. Bridge	HSO	European Space Agency
Mr J. S. Campbell	HSO	European Space Agency
Mr J. M. Humphreys	SO	ECMWF
Mr D. E. Bashford	ASO	European Space Agency

Staff returning from international and other secondment appointments were:

Mr C. T. Little	HSO	ECMWF
Mr J. Nelson	TTO III	New Hebrides

HONOURS AND DISTINCTIONS

The Director-General, Sir John Mason, C.B., F.R.S., was created a Knight Bachelor in the Birthday Honours List 1979.

The London Mathematical Society awarded its Naylor Prize and Lectureship to Sir John Mason for distinguished contributions to the application of mathematics. Sir John is the second recipient of the Prize, the first having been Sir James Lighthill.

The Queen's University of Belfast elected Sir John Mason to the Larmor Lectureship for 1979.

The Imperial Service Medal was presented to Mr R. I. Jones by the Director-General on 5 October 1979.

The L. G. Groves Memorial Prize for Meteorology was awarded to Mr D. E. Miller, Assistant Director (High Atmosphere).

APPENDIX I

BOOKS OR PAPERS BY MEMBERS OF THE STAFF

ATKINS, MARGARET J., B.Sc.; The use of satellite sounding data in routine weather forecasting. BOLLE, H. J. (editor), Remote sounding of the atmosphere from space. Oxford Pergamon Press, 1979, 9–9.

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AXFORD, D. N., Ph.D., C.Eng., M.I.E.E.; The use of automatic weather stations in the observational network of the United Kingdom. *Meteorol Mag*, **108**, 1979, 1–10.

BADER, M. J., M.Sc., D.I.C. and WARRILOW, D. A., B.Sc.; Why was it dry in the autumn of '78? *Water, London*, No. 25, 1979, 2–5.

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CARSON, D. J., Ph.D.; Representation of surface properties and exchanges in large-scale numerical models. ICSU/WMO, GARP Working Group on Numerical Experimentation, Report No. 19, Geneva, 1979, 45–46.

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CAUGHEY, S. J., Ph.D. *in* MOULSEY, T. J., COLE, R. S., ASIMAKOPOULOS, D. N. and CAUGHEY, S. J.; Simultaneous horizontal and vertical acoustic sounding of the atmospheric boundary layer. *Boundary-Layer Meteorol, Dordrecht*, **17**, 1979, 223–230.

CAUGHEY, S. J., Ph.D. and PALMER, S. G., B.Sc.; Some aspects of turbulence structure through the depth of the convective boundary layer. *Q J R Meteorol Soc*, **105**, 1979, 811–827.

CAUGHEY, S. J., Ph.D. and WYNGAARD, J. C.; The turbulence kinetic energy budget in convective conditions. *Q J R Meteorol Soc*, **105**, 1979, 231–239.

CAUGHEY, S. J., Ph.D., WYNGAARD, J. C. and KAIMAL, J. C.; Turbulence in the evolving stable boundary layer. *J Atmos Sci, Boston, Mass.*, **36**, 1979, 1041–1052.

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CULLEN, M. J. P., Ph.D. and HALL, C. D., B.Sc.; Forecasting and general circulation results from finite element models. *Q J R Meteorol Soc,* **105,** 1979, 571–592.

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FOLLAND, C. K., B.Sc., Grad. Inst. P.; Scientific aspects of the 1975–76 drought in England and Wales. *Bull Sci Hydrol,* **23,** 1978, 302–304.

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GILCHRIST, A., M.A.; Concerning general circulation models. *Meteorol Mag,* **108,** 1979, 35–51.

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APPENDIX II

A SELECTION OF LECTURES AND BROADCASTS GIVEN BY MEMBERS OF STAFF

ADAMS, R. J., Ph.D.

Methods of irrigation. *Five lectures to MAFF Agricultural, and Drainage and Water Supply Officers, East Midlands.* March and April.

The availability of meteorological data of especial relevance to drainage and irrigation. *Regional Conference of ADAS Land Drainage Service, Moulton, Northants.* 3 April.

The importance of weather in spraying operations. *Meeting on 'Application of pesticides from ground-based sources', College of Aeronautics, Cranfield Institute of Technology.* 23 July.

The weather of autumn 1978 and spring 1979 in the context of suitability for agricultural spraying. *British Crops Protection Council Conference on review of herbicide usage, London.* 29 October.

Weather conditions associated with blowing soils in East Anglia. *Contribution to 'Farming Today', BBC Radio 4.* 23 July.

ALLARDICE, J.

Weather services for sportsmen. *Radio Clyde.* 23 October.

ALLEN, J. J.

Meteorology for yachtsmen. *Series of lectures to Royal Yachting Association Yachtmasters' Courses, Fleet, Hants and Guildford, Surrey.* Spring Term.

ATKINS, J. E.

Work in the Meteorological Office on ocean current observations from ships on passage. *The Challenger Society, Wormley.* 25 April.

Climate of the south-western approaches and the western English Channel – some comparisons with the North Sea. *Society for Underwater Technology Seminar, London.* 23 October.

ATKINS, MARGARET J., B.Sc.

Computers on weather forecasting. *East Anglia branch of the British Computer Society, Norwich.* 2 April.

AXFORD, D. N., Ph.D., C.Eng., M.I.E.E.

Automatic Weather Stations (AWS) – current developments and future prospects. *Public talk to Advisory Committee on Meteorology for Scotland and others, Edinburgh.* 30 May.

BACON, J. D., FISH, M. J., GILES, W. G. and SCOTT, J.

No business like snow business (survey of weather in 1979). *BBC TV.* 30 December.

BADER, M. J., M.Sc., D.I.C.

Meteorological aspects of drainage design. *PTRC Drainage Design Course, London.* 2 May.

BAYLISS, J. M.

Weather forecasting and ship routeing. *Avon Branch of the Nautical Institute, Bristol.* 23 January.

BENNETTS, D. A., Ph.D.

The low-level cold-frontal jet. *Third United Kingdom Geophysical Assembly, University of Southampton.* 5 April.

Conditional symmetric instability – a possible explanation for frontal rain bands. *Royal Meteorological Society, London.* 17 October.

The dynamics of a cumulonimbus cloud; a joint numerical and observational study. *Royal Meteorological Society Discussion Meeting on 'Convection Downdraughts in Storms', London.* 21 November.

BEST, K. E.
Weather forecasting.
Chartered Surveyors Sailing Association. 21 February.
Guildford Coastal Cruising Association. 20 March.
International activities of the Meteorological Office. *BBC Radio Solent.* 19 March.
Weather forecasts. *Institute of Clerks of Works, Brighton.* 19 May.
Weather during the Fastnet Race.
BBC TV (South). 17 August.
BBC Radio Solent. 21 August.
Chartered Surveyors Sailing Association. 21 August.

BEST, K. E. and LAIRD, B.
Series of lectures on meteorology during Yachtmasters' Course. *National Sailing Centre, Cowes.* 30 November to 2 December.
The Yachtsman's Weather Map. *Royal Yachting Association Course for Master Yachtmaster.* 24 November.

BLACKALL, R. M., B.Sc.
Lectures and instruction at the Royal Meteorological Society Field Study Course on 'Mountain Weather', Betws-y-Coed, Gwynedd. 25 July to 1 August.
Understanding the weather. *Series of 10 lectures to the Workers Educational Association, Bracknell, Berks.* Between 27 September and 6 December.

BORRETT, P. D., B.Sc. and NORRIS, J.
Meteorological organization and services for civil aviation. *Civil Aviation Authority Induction Course at School of Navigation, City of London Polytechnic.* 28 November.

BROWN, D. W.
Meterology for yachtsmen. *Course of 12 lectures at Bath Technical College.* January to March.
General meteorology.
Course of 10 lectures to the Workers Educational Association, Pewsey, Wilts. January to March.
Series of evening talks to Women's Institutes, Burbage, Wilts. March.
Series of evening talks to Farmers' Associations: Wiltshire Farmers Club, and Marlborough Young Farmers. April.
Course of 10 lectures to the Workers Educational Association, Wanborough, Wilts. October to December.

BROWN, R., B.Sc.
Some aspects of the physics of radiation fog. *Royal Meteorological Society, Manchester Centre.* 22 November.

BROWNING, K. A., Ph.D., D.I.C., F.R.S.
Orographic rain.
Imperial College Environmental and Meteorological Society, London. 13 March.
Royal Meteorological Society Scottish Centre, Edinburgh. 12 October.
CSIRO Division of Atmospheric Physics, Bureau of Meteorology, Melbourne. 13 December.
Radar as part of an integrated system for measuring and forecasting rain. *Invited lecture at ICCP Symposium on 'Remote Sensing of Cloud Parameters', IUGG General Assembly, Canberra.* 11 December.

COCHRANE, J.
Meteorology and agriculture. *Lectures and Debates Society, School of Agriculture, University of Nottingham.* 6 March.
Weather and sugar beet. *Broom's Barn Experimental Station, Higham, Bury St Edmunds, Suffolk.* 5 December.

COLLIER, C. G., B.Sc., A.R.C.S.

The Meteorological Office Short Period Forecasting Pilot Project.
Royal Meteorological Society Discussion on Short Period Weather Forecasting, London. 21 February.
MOD(PE), London. 27 April.
Symposium on Digital Radar Reflectivity Processing with Applications to Hydrometeorology, Edmonton, Canada. 17 October.

COWLEY, J. P., M.Sc.

Solar radiation measurements and archives in the UK Meteorological Office, Bracknell. *Conference on 'Meteorology for Solar Energy Applications' organized by the UK International Solar Energy Society, London.* 24 January.

CULLEN, M. J. P., Ph.D.

The treatment of blocking patterns by large numerical forecasting models. *Royal Meteorological Society Specialist Group on Dynamical Problems, London.* 27 September.

Forecasting variability using different models. *ECMWF Workshop on stochastic models, ECMWF, Shinfield Park.* 18 October.

Comparative forecast studies made at the Meteorological Office. *Royal Meteorological Society Review Meeting, London.* 12 December.

DAVIES, T., Ph.D.

The UK Meteorological Office forecast model intercomparison experiment. *Fourth Conference on Numerical Weather Prediction, Washington, D.C.* 30 October.

DEEKS, P. H. G.

Weather forecasting.
Yachtmasters' Course, Woking. 7 March.
Workers Educational Association, Haslemere. 15 March.
Yachtmasters' Course, Surbiton. 10 May.
Fleetway Cruising Association. 3 October.

Meteorology in relation to building. *Cement and Concrete Association, Slough.* 10 September.

DENT, L., B.Sc.

Meteorology. *Air Transport Planning and Operations Course, Cranfield Institute of Technology.* 15 November.

DOUGLAS, H. A., B.Sc.

Climatological information. *Interview with BBC Radio Scotland.* 12 February.

Meteorological instrumentation. *Department of Meteorology, University of Edinburgh.* 10 May.

DUTTON, M. J. O., B.Sc.

Wind and aircraft. *Royal Meteorological Society Summer Meeting, Stirling.* 23–24 May.

Prediction of clear-air turbulence towards probability forecasts based on numerical model output. *Technical Conference on Aviation Meteorology, WMO, Geneva.* 5–9 November.

EBDON, R. A.

A climatological and historical introduction. *Royal Meteorological Society meeting on 'Stratospheric Warmings', London.* 17 January.

EMERY, P. F.

Weather forecasts. *Durham Meteorological Society.* 9 February.

Severe weather. *BBC TV (North).* 19 March.

Weather. *Royal National Lifeboat Institution.* 13 November.

FISH, M. J.
Weather.
Series of broadcasts for BBC Radio Schools program. March.
Swimming Pools Association. 5 April.
Satellite radar meteorology. *BBC TV 'Sky at Night' program (with Patrick Moore).* 30 May.
Weather forecasting.
Physically Handicapped Club, Stevenage. 16 July.
Leicester Concorde Club. 11 September.
The work of a weather centre. *Midland Bank Accountants' Club.* 20 November.

FLAVELL, R. G.
Meteorological observations from ships via Meteosat and TIROS-N. *Conference on the utilization of ARGOS, Toulouse.* 29 March.

FLOOD, C. R., M.A.
The economic effects of climatic changes. *Royal Meteorological Society, Cardiff.* 29 September.

FRANCIS, P. E., Ph.D.
Some climatic factors in land assessment. *Symposium on Land Assessment in Scotland, Royal Scottish Geographical Society, Department of Geography, University of Edinburgh.* 25 May.

GADD, A. J., Ph.D.
The Meteorological Office operational model and its behaviour. *ECMWF seminar, ECMWF, Shinfield Park.* 25 October.
Has technology improved weather forecasts? *Royal Meteorological Society Sixth Form Lecture, County Hall, London.* 6 and 7 December.

GILCHRIST, A., M.A.
Results of experimental forecasts for the GATE area. *Woods Hole Oceanographic Institute, Mass.* 27 August.
The performance of the Meteorological Office forecast model in the tropics. *Woods Hole Oceanographic Institute, Mass.* 28 August.

GILES, W. G.
Cold weather. *BBC TV (Scotland).* 8 February.
Weather. *Chiltern Hundreds Club.* 11 September.
Caribbean hurricanes. *BBC 2 (TV) Late News.* 31 August.
The differences between aviation and public service forecasting. *London University Air Squadron.* 22 November.
The use of satellite imagery in forecasting. *Geography Department, University of Exeter.* 28 November.

GOLDING, B. W., B.Sc.
Winds and wave forecasting. *Part of a short course on Ocean Waves for Engineering Design, University of Liverpool.* 10 January.
Computers in weather forecasting. *Middlesbrough Branch of the British Computer Society and the North East Operational Research Group.* 14 March.
Computer calculations of waves from wind fields. *Institute of Mathematics and its Applications Conference on Power from Sea Waves, Edinburgh.* 28 June.

GOLDSMITH, P., M.A.
Weather/climate modification.
Part I, University of Reading. 12 March.
Part II, University of Reading. 19 March.
An introduction to pollution problems involving stratospheric ozone. *Royal Meteorological Society, London.* 11 April.
Visibility trends in the UK—evidence for increased photochemical activity. *Symposium on Trace Gases and Aerosols in the Atmosphere, Boulder, Col.* 16 August.

HIDE, R., Sc.D., F.R.S.

Rotating fluids and planetary atmospheres.
Clarendon Laboratory, University of Oxford. 27 February.
Department of Meteorology, University of Reading. 20 March.

Mathematics flux linkage of a moving medium.
Mathematics Department, University College, London. 9 February.
British Theoretical Mechanics Colloquium, University of Southampton. 2 April.

A new method for determining the size of the electrical-conducting fluid core of a planet in which dynamo action is occurring; applications to Earth and Jupiter.
UK Geophysical Assembly, University of Bath. 5 April.
Royal Astronomical Society meeting, University of Durham. 9 April.
US Geological Survey, Golden, Col. 25 June.

Shock magnetization and the origin of extraterrestrial palaeomagnetism. *Royal Astronomical Society meeting, University of Durham.* 9 April.

Planetary magnetic fields. *Astronomical Society, University of Leeds.* 9 April.

Regular baroclinic waves.
Conference on Comparative Fluid Dynamics, Annapolis, Md. 12 June.
National Center for Atmospheric Research, Boulder, Col. 27 June.
Woods Hole Oceanographic Institute, Mass. 25 July.

Dynamics of Jupiter's atmosphere. *National Center for Atmospheric Research, Boulder, Col.* 5 July.

Recent work on rotating fluids. *Geophysical Fluid Dynamics Laboratory, Princeton, N.J.* 16 July.

The magnetic flux linkage of a moving medium: a theorem and applications. *International Symposium on Dynamo Theory and the Generation of the Earth's Magnetic Field, Alsovice, Czechoslovakia.* 16 October.

The rotation of Jupiter's atmosphere and interior. *Interdisciplinary Symposium on Geophysical Implications of Planetary Studies, 17th General Assembly of IUGG, Canberra, Australia.* 7 December.

Angular momentum transfer in the earth-atmosphere system. *Interdisciplinary Symposium on Relationships between the Earth's Rotation and Geophysical Phenomena, 17th General Assembly of IUGG, Canberra, Australia.* 4 December.

Bumps on the core-mantle boundary: geomagnetic and gravitational evidence revisited. *Interdisciplinary Symposium on Dynamics of Core and Mantle, 17th General Assembly of IUGG, Canberra, Australia.* 8 December.

Some recent work on the hydromagnetics of rotating fluids and dynamos. *Symposium on Planetary Dynamo Theory, International Association of Geomagnetism and Aeronomy, Canberra, Australia.* 10 December.

HILLS, T. S., B.A.

The treatment of mountains in a general circulation model of the atmosphere and the model's sensitivity to mountain heights. *Euromech meeting 'Airflow over hills and mountains', Siegsdorf, Federal Republic of Germany.* 5 April.

Sensitivity of numerical models to mountain representation. *ECMWF Workshop on Mountains and Numerical Weather Prediction, ECMWF, Shinfield Park.* 20 June.

HOPKINS, J. S., B.Sc., A.R.C.S.

Meteorological Office services for hydrology: what rainfall data does Scotland need? *Institution of Civil Engineers, Scottish Hydrological Group, Glasgow.* 12 January.

The planning of observational networks—the theory and practice. *Royal Meteorological Society, Scottish Centre, Edinburgh.* 9 February.

Cloud, rain and snow; meteorological information for planning and design. *Lectures at Royal Meteorological Society Course on 'Meterology for Civil Engineering and Building', University of Reading.* 29 March.

Royal Meteorological Society Summer Meeting at Stirling. *Interview with BBC Radio Scotland.* 22 August.

HOUGH, M. N., Ph.D.

The agricultural climate—its use in planning for higher yields. *ICI 'Wheatrace' conference, London.* 8 March.

The effects of weather on crop growth. *Royal Agricultural Society of England conference, Stoneleigh, War.* 14 March.

HOUGHTON, D. M., M.Sc., D.I.C.

Long-term weather trends and long-range forecasting. *Annual Conference of the British Sugar Corporation, Stratford-upon-Avon, War.* 27 February.

Long-range forecasting. *Seminar, University of Reading.* 2 March.

Weather and the movement of exports. *Meeting of Reading and District Export Club.* 14 March.

Climatic variability over the UK and its impact on the national economy. *International Conference on Climate and History, University of East Anglia.* 13 July.

Variability of weather and climate. *Lecture at the Association of London Graduates and Students, Institution of Civil Engineers.* 3 October.

Local weather phenomena in the Gulf of Tallinn. *British Olympic Yacht Training Conference, Calshot.* 13 October.

Long-range forecasting, science or sorcery? *Royal Meteorological Society, East Midlands Centre, Sutton Bonington.* 13 November.

Discussion on long-range forecasting on Southern TV 'Day by Day' program. 30 November.

HOUGHTON, D. M., M.Sc., D.I.C., MORRIS, R. M., B.Sc. and SCOTT, J.

Come rain, come shine. *BBC Documentary on the work of the Meteorological Office, BBC TV (South).* 11 December.

HULL, O. M.

Weather forecasting.

Series of lectures to Youth Community Service, London Borough of Brent. 28 February, 14 and 28 March.

East Midlands Cruising Association, Melton Mowbray. 14 December.

HUNT, R. D., B.Sc.

Forecasting severe weather. *Contribution to film 'International Weather Report' for American TV.* 1 August.

Weather. *Phone-in program on BBC Radio Oxford.* 27 September.

Modern weather forecasting. *County Surveyors Society, Exeter.* 23 November.

INGHAM, B.

Agricultural meteorology. *Farmers Discussion Group, Sherborne, Dorset.* 10 January.

JAMES, I. N., Ph.D.

Some aspects of baroclinic wave motion in meteorology. *Department of Mathematical Physics, University College, Dublin.* 16 January.

Solitons and baroclinic waves.

Department of Mathematics, University College, London. 9 February.

Atmospheric Physics Department, University of Oxford. 14 February.

British Theoretical Mechanics Colloquium, University of Bath. 4 April.

JAMES, P. K., D.Phil

Mesoscale structure of line convection at surface cold fronts. *Royal Meteorological Society Meeting, London.* 17 October.

JENKINSON, A. F., I.S.O., M.A.

Prediction of weather sequences by autoprojective methods. *Meeting of Royal Statistical Society, Reading Branch.* 17 August.

JOHNSON, A. I., B.Sc.

The use of satellites in meteorology. *Royal Institute of Chartered Surveyors, Wessex Branch, Southampton.* 8 March.

The use of satellites in weather forecasting. *Sixth Form Lecture, Royal Meteorological Society Welsh Centre, Cardiff.* 22 November.

JONAS, P. R., Ph.D., D.I.C.

Laboratory studies of topographic effects on baroclinic fluids.
Euromech meeting on 'Airflow over Hills and Mountains', Siegsdorf, Federal Republic of Germany. 5 April.
ECMWF Workshop on 'Mountains and Numerical Weather Prediction', ECMWF, Shinfield Park. 20 June.

KERSHAW, R.

Modern methods of weather forecasting. *Institution of Electrical Engineers, Sheffield Centre.* 1 November.

KIDD, J. G. R.

The work of Manchester Weather Centre. *Federation of Cricket Groundsmen.* 11 December.

KING, E. G. E.

Driving rain and cavity-wall insulation. *Association of British Climatologists, University of Reading.* 12 September.

Weather services for the construction industry. *Institute of Building, Bedford.* 19 September.

LAIRD, B.

Weather. *Yachtmasters' Course, Gosport.* 16 January.

Sea fog. *BBC Radio Solent.* 14 May.

LOVE, JANE P.

Weather and agriculture. *Strathearn Junior Agricultural Club, Crieff, Tayside.* 18 October.

LYNE, W. H., Ph.D.

The Meteorological Office FGGE data assimilation experiment. *Conference of Commonwealth Meteorologists, Meteorological Office College, Shinfield Park.* 6 June.

A global data assimilation scheme using FGGE data. *4th Conference on Numerical Weather Prediction, Washington, D.C.* 1 November.

MACKIE, G. V.

The Meteorological Office Ship Routeing Service. *Department of Maritime Studies, Liverpool Polytechnic.* 22 March.

MCCASKILL, J. R., B.A.

Weather forecasting. *Manchester Branch of the Royal Meteorological Society. 22 February.*

MCKELLAR, H. A.

Weather. *Agricultural Discussion Group, Bridge of Weir, Strathclyde.* 13 March.

MARSHALL, G. A.

The work of Weather Centres in relation to outdoor pursuits. *National Trust, Wilmslow.* 16 November.

Weather forecasting. *Manchester Philosophical Society.* 10 December.

MASON, SIR JOHN, C. B., D.Sc., F.R.S.

Observation of the world's weather in the satellite age. *University of Bristol.* 5 February.

The physics of a raindrop.
University of Oxford, Scientific Society. 2 March.
The Institute of Physics (Irish Branch), University College, Cork. 2 April.
The Institute of Physics (Irish Branch), University College, Dublin. 3 April.

Computer modelling of weather and climate. *Physics Department, University of Southampton.* 15 March.

The numerical prediction of weather and climate. *The Naylor Lecture of the London Mathematical Society, London.* 16 March.

The atmospheres of the planets.
The Rutherford Laboratory. 17 April.
The Poynting Lecture, University of Birmingham. 25 June.

The role of satellites in the First GARP Global Experiment. *NOAA Scientific Colloquium at WMO, Geneva.* 5 May.

Numerical modelling of global climate and possible man-made changes. *The Larmor Lecture, Queen's University, Belfast.* 25 October.

Numerical weather prediction. *Atmospheric Environment Service, Toronto, Canada.* 10 October.

Numerical modelling of global climate and the effects of human activities. *The Andrew Thomson Lecture, University of Toronto.* 11 October.

The prediction of weather and climate with the aid of large electronic computers. *Institution of Electrical Engineers, London.* 6 December.

The meteorological effects of increasing the carbon-dioxide content of the atmosphere. *Council for Environmental Science and Engineering conference on 'The environmental effects of burning more coal', London.* 11 December.

MASON, P. J., Ph.D.

Numerical integrations of the Navier-Stokes equation for flow over surface-mounted obstacles. *University of Cambridge.* 2 February.

An illustrated talk on the facets of rotating fluids. *Royal Aeronautical Society, Bedford Branch.* 22 February.

Rapidly rotating flow over surface-mounted obstacles. *British Theoretical Mechanics Colloquim, University of Bath.* 3 April.

Mountains and numerical mesoscale models. *ECMWF, Shinfield Park.* 21 June.

A two-dimensional numerical study of horizontal roll vortices in the neutral atmospheric boundary layer. *2nd International Symposium on 'Turbulent Shear Flows', Imperial College, London.* 3 July.

MAY, B. R., B.Sc.

Solar radiation data for the UK and overseas. *Solar Trade Association, London.* 12 September.

UK Meteorological Office activity in Tasks IV and V of the International Energy Agency Solar Heating and Cooling Program. *Conference on the Government Solar Energy Program organized by the Department of the Environment.* 15 and 16 October.

MENMUIR, P., B.Sc.

Some examples of the use of video displays of radar and satellite products. *Royal Meteorological Society Discussion Meeting on 'Short Period Weather Forecasting', London.* 21 February.

MILLER, D. E., B.A.

Quantitative analysis of radiance data. *ESA/WMO Technical Conference on use of data from meteorological satellites, Trégastel, France.* 18 September.

MITCHELL, J. F. B., Ph.D.

Do Man's activities affect the climate at present: are they likely to do so in the future? *Royal Meteorological Society Welsh Branch Meeting on Climatic Change, UWIST, Cardiff.* 29 September.

MOLONEY, L.
Weather forecasts. *Southwell Young Farmers' Club.* 3 December.

MORRIS, R. M., B.Sc.
Weather. *Phone-in program on Capital Radio.* 19 January.
Meteorology in relation to low-level flight over the sea. *Royal Aeronautical Society Symposium on Man Powered Flight, London.* 6 February.
Weather during the Fastnet Race.
BBC Radio 4 'World at One'. 15 August.
London Broadcasting Company. 16 August.
Real-time meteorological and oceanographic data. *Society for Underwater Technology, London.* 23 October.

NICHOLASS, C. A., B.Sc.
Rain-gauge network rationalization. *Institution of Civil Engineers, London.* 12 March.

OGDEN, R. J., B.Sc.
Weather in relation to pigeon racing. *Midlands Circle of Pigeon Fanciers, Grantham.* 24 March.
Weather and climate and surface wind. *Lectures at Royal Meteorological Society Course on 'Meteorology for Civil Engineering and Building', University of Reading.* 29–30 March.
Meteorological conditions affecting soil moisture content. *Lecture at Centre for Advanced Land Use Studies Course on 'Building Subsidence', Ware.* 7 June.
Short-range forecasting. *WMO Technical Conference on Aviation Meteorology, Geneva.* 7 November.
Weather during the Fastnet Race. *BBC TV 'Man Alive' program.* 11 December.

O'NEILL, A., Ph.D.
A study of the major stratospheric warming of 1976/77 (Text written with B. F. Taylor). *Royal Meteorological Society Meeting, London.* 17 January.
The dynamics of stratospheric sudden warmings.
Seminar, Atmospheric Environmental Sciences Division, NASA Langley Research Center, Hampton, Va. 7 March.
Seminar, Department of Atmospheric Physics, University of Washington, Seattle, Wash. 6 April.
Momentum, heat and energy transports in the stratosphere. *Third United Kingdom Geophysical Assembly, University of Southampton.* 4 April.
The dynamics of planetary waves in the stratosphere. *Seminar, University of Edinburgh.* 6 September.
Stratospheric dynamics: wave structure. *NATO Advanced Study Institute Meeting on Atmospheric Ozone; its variations and human influences, Aldeia das Acoteias, Portugal.* 9 October.
Stratospheric sudden warmings. *NATO Advanced Study Institute Meeting on Atmospheric Ozone; its variations and human influences, Aldeia das Acoteias, Portugal.* 10 October.

OWENS, R. G., B.Sc. and MONK, G., B.Sc.
Short Period Weather Forecasting Pilot Project. *Display presented at the Royal Agricultural Show, Stoneleigh, War.* 2–5 July.

PAINTER, H. E., B.Sc.
Maintenance and instrumentation of network stations to measure solar radiation. *Meeting on 'Extension of Radiation Networks, Improvement of Equipment and Use of Satellite Data' organized by the EEC under its Solar Energy R and D Program Project F (Solar Radiation Data Acquisition), Valbonne, France.* 4 and 5 May.

PAINTING, D. J., B.Sc.

The Meteorological Office Marine Archive and its use to describe ocean climate. *Symposium on Commercial Sail, Royal Institute of Naval Architects, London.* 14 June.

The Variability of Wind and Wave Statistics as observed at Ocean Weather Ship 'I'. *International Conference on Sea Climatology, Paris.* 4 October.

PALMER, T. N., D.Phil.

Aspects of the magnetic flux linkage theorem of Hide. *Discussion, Dynamics and Magnetohydrodynamics of Rotating Fluids Group, University College, London.* 8 June.

PARKER, D. E., B.Sc.

Characteristics and consequences of climatic variability. *International Conference on Climate and History, University of East Anglia.* 13 July.

Natural causes of climatic change. *Royal Meteorological Society Welsh Branch Meeting, UWIST, Cardiff.* 29 September.

PARKER, G. H.

Weather forecasting.

Yachtmasters' Course, Morden. 1 February.

Civil Service Retirement Fellowship, Kingston. 15 May.

Surrey Naturalists Society, Leatherhead. 22 November.

Society of Chemical Manufacturers, London. 13 December.

Weather and science. *London Junior Chamber of Commerce.* 7 March.

Weather. *Horsham Natural History Society.* 12 April.

The work of London Weather Centre. *BBC Radio London.* 21 June.

PARTINGTON, S. J. G.

Climatology and the Building Industry. *Royal Ulster Society of Architects, Belfast.* 29 March.

PEPPERDINE, E. J.

Mathematics in meteorology. *Leicestershire Mathematics Association, University of Leicester.* 9 March.

Weather Centre services. *Nottingham Business Club.* 8 June.

PERRY, J. D., B.Sc.

Climatology of blocking. *Meeting of Royal Meteorological Society Specialist Group on Dynamical Problems, London.* 27 September.

PHILLIPS, M. G.

Conversion to JES3 from ASP—a user's experience. *Online International Conference—IBM/MVS Operating System, London.* 3 April.

PICK, D. R., D.Phil.

Results from the Meteorological Office SSU on TIROS-N. *Seminar, Atmospheric Physics Department, University of Oxford.* 22 February.

RACKLIFF, P. G.

The production and use of the Effective Downwind Message. *UKWMO Continental Liaison Officers, Home Office, London.* 16 November.

RICHARDS, P. J. R., M.A.

Problems of designing a boundary-layer scheme based on an eddy diffusion coefficient approach. *Seminar, University of Reading.* 12 March.

RIDDAWAY, R. W., Ph.D.

The use of man in weather forecasting. *Royal Meteorological Society, Scottish Centre, Edinburgh.* 12 June.

The science and art of weather forecasting. *Geographical Association, Liverpool Branch.* 15 November.

ROACH, W. T., Ph.D., D.I.C.
Aviation meteorology. *College of Aeronautics, Cranfield, Beds.* 16 March.
The role of meteorology in aviation. *Royal Aeronautical Society, Yeovil Branch.* 27 September.
Fog in relation to transport. *Royal Meteorological Society, Welsh Branch, Swansea.* 25 October.

ROWNTREE, P. R., Ph.D.
Ocean–atmosphere interactions in climate modelling. *Royal Meteorological Society Specialist Group on Dynamical Problems, Imperial College, London.* 8 March.
Climate modelling with special reference to the carbon dioxide problem. *Conference of Commonwealth Meteorologists, Meteorological Office College, Shinfield Park.* 6 June.

ROY, MARJORY G., M.Sc.
Agricultural effects of the 1975–76 drought. *School of Agriculture, University of Nottingham.* 1 March.

RYDER, P., Ph.D.
The physics of cloud and precipitation. *Physics Department, University of Warwick.* 16 March.
Atmospheric fronts. *Third United Kingdom Geophysical Assembly, University of Southampton.* 5 April.
Cloud physics research. *Physics Department, University of Leeds.* 29 November.

SAYERS, T. J.
Weather forecasting. *Phone-in program on BBC Radio Manchester.* 7 June.

SCOTT, J.
Severe winter weather. *Recorded report for Japanese TV.* 8 March.
Understanding the weather. *Royal Agricultural Society of England, Stoneleigh, War.* 14 March.
Weather forecasting. *Royal Meteorological Society Course on 'Meteorology for Civil Engineering and Building', University of Reading.* 30 March.
Weather.
Royal Association of British Dairymen. 21 June.
National Clean Air Society Conference, Scarborough. 16 October.
The work of a Weather Centre. *Milk Marketing Board.* 4 September.
The weather business. *Buckley Lecture at Nene College, Northampton.* 9 October.

SHAW, D. B., B.Sc.
The Meteorological Office 4-D assimilation experiment during FGGE special observing periods 1 and 2. *Royal Meteorological Society Specialist Group on Dynamical Problems, ECMWF, Shinfield Park.* 9 November.

SHORNEY, P. W.
Meteorological services for growers. *Talk to mark the British Growers 'Look ahead' Exhibition, BBC Radio Brighton.* 4 April.
Weather forecasting.
Barclay Assistant Managers Club. 22 May.
South Downs Astronomical Society. 7 September.
Hampshire Herdsmen's Club. 7 November.

SIMMONS, E. L., D.Phil.
Monitoring of ozone—ground-based measurements. *Royal Meteorological Society Discussion Meeting on 'Influence on Stratospheric Ozone', London.* 11 April.
Long-term monitoring of global ozone levels and some thoughts on monitoring experiments at certain levels in the stratosphere. *Seminar, Centre National de la Recherche Scientifique, Service d'Aéronomie, Verrières-le-Buisson, France.* 11 May.

SLATTERY, P. J.
Weather forecasting. *Stocksfield Horticultural Society.* 15 May.

SLINGO, JULIA M., B.Sc.

Modelling climate. *Royal Meteorological Society Welsh Branch Meeting on 'Climatic change', UWIST, Cardiff.* 29 September.

Clouds, cloud modelling, radiation and climate. *Seminar, University of Liverpool.* 30 November.

SMITH, C. V., M.A., B.Sc.

Utilization of labour. *Kent County Agricultural Society, Detling, Maidstone, Kent.* 17 January.

Weather—the unknown factor. *Hampshire Cereal Growers, Sparsholt, Hants.* 1 February.

Aerobiology. *Seventh Session of the Commission for Agricultural Meteorology, Sofia, Bulgaria.* 25 September.

Using available information constructively. *Centre for Farm Management Annual Conference, Malvern, Hereford and Worcs.* 8 November.

Weather and work days. *Royal Meteorological Society Specialist Group for Agricultural Meteorology, University of Reading.* 14 November.

SPARKS, W. R., B.Sc.

Agricultural meteorology.

New Entrants Course, ADAS, Bristol. 8 February.

ADAS, Exeter. 20 February.

Weather and haymaking. *Farmers Discussion Group, Truro.* 26 April.

STARR, J. R., Ph.D., D.I.C.

Weather on the farm.

Physical Society, University of Reading. 1 February.

Windsor Forest Farming Group, Windsor, Berks. 13 February.

Maidenhead Young Farmers Club, Maidenhead, Berks. 10 April.

Meteorological advice for agriculture. *Dairy Discussion Group, Ashford, Kent.* 14 March.

Physics of rain, snow and hail. *Guest lecture, Sixth Form Mathematical Conference, University of Southampton.* 21 March.

What do windbreaks do?

Windbreak Workshop, MAFF, Efford, Everton, Hants. 21 April.

Open Day, MAFF, Luddington, Stratford-upon-Avon, War. 27 September.

Tornadoes, Hurricanes and Floods. *International Emergency Action Organization, Rogate Field Centre, Hants.* 5 July.

Recent work on the prediction of soil water deficits. *ADAS Soil Scientists Training Course, Berkshire College of Agriculture, Burchetts Green, Maidenhead, Berks.* 7 July.

Gastro-intestinal nematode infection in lambs. *Eighth International Biometeorology Congress, Tel Aviv, Israel.* 12 September.

Weather and viticulture. *Bracknell Wine Circle, Bracknell, Berks.* 5 October.

Weather and the fruit grower. *East Sussex Fruit Group, Battle.* 13 December.

SYKES, R. I., Ph.D.

Two-dimensional study of large eddies in the atmospheric boundary layer. *University of Cambridge.* 2 February.

Two lectures: (1) Numerical integrations of the Navier–Stokes equation for flow over surface mounted obstacles, (2) Experimental observations of flow over hills. *Euromech meeting on 'Airflow over Hills and Mountains', Siegsdorf, Federal Republic of Germany.* 2–5 April.

THOMPSON, N., Ph.D.

The bulk resistance to drying of a haycrop in the field. *Hay Research Discussion Group, Berkshire College of Agriculture, Burchetts Green, Maidenhead, Berks.* 5 January.

The ways of the weather. *Institute of Medical Laboratory Sciences, Reading Branch.* 10 May.

Weather and work days for hay drying. *Royal Meteorological Society Specialist Group for Agricultural Meteorology, University of Reading.* 14 November.

TUCK, A. F., Ph.D.

The simultaneous effects of CO_2 and chlorofluoromethanes on stratospheric ozone. *Royal Meteorological Society Meeting, London.* 11 April.

Anthropogenic gases and the ozone layer. *Interview for BBC Overseas Service.* 30 July.

Atmospheric chemistry. *Seminar at ECMWF, Shinfield Park.* 15 November.

TYLDESLEY, J. B., B.A.

Non-linear temperature effects—how to handle the response to the environment. *Department of Plant Sciences, University of Leeds.* 26 September.

WAKELIN, P.

The development of severe weather in remote and mountainous areas. *Royal Military Academy, Sandhurst.* 2 and 5 October.

WALES-SMITH, B. G.

The Meteorological Office Rainfall and Evaporation Calculation System. *Institute of Hydrology, Wallingford, Oxon.* 7 February.

The measurement of rainfall and evaporation and some uses of the data. *Severn-Trent Water Authority, Birmingham.* 4 May.

WATKISS, B. O.

Weather forecasting. *Phone-in program on BBC Radio Brighton.* 19 July.

Hurricanes. *BBC Radio Solent.* 4 September.

WHITE, A. A., Ph.D.

Non-Doppler effects in rotating fluids. *UK Universities Atmospheric Modelling Group, University of Reading.* 8 January.

WHITE, P. W., Ph.D.

Supercomputers and the prediction of weather and climate. *University of Cambridge.* 31 January.

The work of the mesoscale modelling group. *Defence Scientific Advisory Council, Meteorological Office College, Shinfield Park.* 4 July.

Mesoscale modelling in the UK Meteorological Office. *University of Karlsruhe, Federal Republic of Germany.* 18 October.

WICKHAM, P. G., M.A.

Six lectures on forecasting methods. *A course for M.Sc. students at the Department of Geophysics, University of Reading.* March to May.

APPENDIX III

PUBLICATIONS

The publications prepared by the Meteorological Office are generally issued by Her Majesty's Stationery Office as official publications. Catalogues listing all the publications which may be purchased through the sales office or usual agents of Her Majesty's Stationery Office, or direct from the Meteorological Office at Bracknell, are sent free to any applicant.

The following publications have been issued:

PERIODICAL

Annual Report on the Meteorological Office 1978.

Daily Aerological Record containing information in respect of meteorological conditions in the upper air for the British Isles.

Daily Weather Report containing weather maps for the northern hemisphere, British Isles, etc., and data.

Monthly Summary of the *Daily Weather Report.*

Monthly Weather Survey and Prospects, a monthly publication containing climatological data for the United Kingdom, the weather of the past month, a general survey and inference, and weather prospects for the coming month in the United Kingdom; a supplementary document, containing survey, inference and prospects only, is published in mid month.

Estimated Soil Moisture Deficit and Potential Evapotranspiration over Great Britain, a seasonal fortnightly publication providing estimates of soil moisture deficit in map form and as a tabular statement for river authority areas.

Sea Ice Charts (daily).

Monthly (coloured) *Ice Maps* (to October 1979).

Meteorological Magazine (monthly).

Monthly Weather Report (to May 1979).

Marine Observer (quarterly).

OCCASIONAL

Handbook of weather messages, Part II, 7th Edition (1979).

Handbook of weather messages, Part III, 6th Edition (1979).

APPENDIX IV

ACRONYMS AND ABBREVIATIONS

AAFCE	Allied Air Forces Central Europe
ACE	Allied Command Europe
ACRE	Automatic Climatological Recording Equipment
ADAS	Agricultural Development and Advisory Service
AFCENT	Allied Forces Central Europe
AGARD	Advisory Group on Aerospace Research and Development
AIS	Aviation Information Service
ASDAR	Aircraft to Satellite Data Relay
ASP	Asymmetric Multiprocessing System
ASR	Altimeter Setting Region
ASSP	Axially Scattering Spectrometer Probe
ATOC	Airfield Tasking Operations Centres
ATWS	Automatic Telephone Weather Service
AUTOCOM	Automated Telecommunication Complex
AUTOPREP	Automatic Message Preparation Equipment
AWS	Automatic Weather Station
BAS	British Antarctic Survey
CAA	Civil Aviation Authority
CAeM	Commission for Aeronautical Meteorology (WMO)
CAgM	Commission for Agricultural Meteorology (WMO)
CAMFAX	Civil Aviation Meteorological Facsimile Network
CARD	Continuous Automatic Remote Display
CAS	Commission for Atmospheric Sciences (WMO)
CBS	Commission for Basic Systems (WMO)
CDC	Control Data Corporation
CEC	Commission of the European Communities
CFO	Central Forecasting Office
CMM	Commission for Maritime Meteorology
CNRS	Centre National de la Recherche Scientifique
COSMOS	Meteorological Office computing system
COSPAR	Committee for Space Research (ICSU)
COST	European Co-operation in Science and Technology
CPU	Central Processing Unit
CRDF	Cathode Ray Direction Finding
DALE	Digital Anemograph Logging Equipment
DEC	Digital Equipment Corporation
EC	Executive Committee (WMO)
ECE	Economic Commission for Europe
ECMWF	European Centre for Medium Range Weather Forecasts
ESA	European Space Agency
FGGE	First GARP Global Experiment (WMO/ICSU)
GARP	Global Atmospheric Research Program (WMO/ICSU)

GATE	GARP Atlantic Tropical Experiment (WMO/ICSU)
GDPS	Global Data Processing System (WMO)
GFDL	Geophysical Fluid Dynamics Laboratory, Princeton, N.J.
GMT	Greenwich Mean Time
GOS	Global Observing System (WMO)
GTS	Global Telecommunication System (WMO)
IAMAP	International Association of Meteorology and Atmospheric Physics (IUGG)
IBA	Independent Broadcasting Authority
IBM	International Business Machines Ltd
ICAO	International Civil Aviation Organization
ICL	International Computers Ltd
ICSU	International Council of Scientific Unions
IMCO	Inter-Governmental Maritime Consultative Organization
IOS	Institute of Oceanographic Sciences
ISO	International Organization for Standardization
IUGG	International Union of Geodesy and Geophysics (ICSU)
JASIN	Joint Air–Sea Interaction Experiment (Royal Society)
JES3	Job Entry Sub-system 3
JOC	Joint GARP Organizing Committee (WMO/ICSU)
JRC	Joint Research Council
LCBR	Laser Cloud Base Recorder
LORAN	Long-range Navigation System
MAFF	Ministry of Agriculture, Fisheries and Food
MCMG	Military Committee Meteorological Group (NATO)
METAG	Meteorological Advisory Group
METSIGAG	Meteorological Services for International General Aviation Group
MMO	Main Meteorological Office
MOD(PE)	Ministry of Defence (Procurement Executive)
MOLFAX	Meteorological Office Land-line Facsimile Network
MORECS	Meteorological Office Rainfall and Evaporation Calculation System
MOTNE	Meteorological Operational Teleprinter Network in Europe
MOWOS	Meteorological Office Weather Observing System
MRF	Meteorological Research Flight
MTER	Magnetic Tape Event Recorder
MVS	Multiple Virtual Storage
MVT	Multiprogramming system with a Variable number of Tasks
NAOS	North Atlantic Ocean Stations
NASA	National Aeronautics and Space Administration, USA
NATO	North Atlantic Treaty Organization
NAVAID	LORAN-C navigational system
NERC	Natural Environment Research Council
NESS	National Environmental Satellite Service (NOAA)
NMC	National Meteorological Centre
NMI	National Maritime Institute
NOAA	National Oceanic and Atmospheric Administration, USA
NORSWAM	North Sea Wave Model
NWS	National Weather Service (NOAA)
ODAS	Ocean Data Acquisition System

OECD	Organization for Economic Co-operation and Development
OWS	Ocean Weather Ship, ocean weather station
PCK	Processor-Controlled Keying
PFO	Principal Forecasting Office
PMP	Possible Maximum Precipitation
PRC	Progress Review Committee
PROMET	Provision of Meteorological Information required before and during flight
PTRC	Planning and Transport Research and Computation (International) Co. Ltd.
RAE	Royal Aircraft Establishment
RAF	Royal Air Force
RCA	Radio Corporation of America
RJE	Remote Job Entry
RMC	Regional Meteorological Centre
RNAS	Royal Naval Air Station
RSRE	Royal Signals and Radar Establishment
RTH	Regional Telecommunication Hub
RVR	Runway Visual Range
SATFAX	Satellite Facsimile Network
SAWS	Synoptic Automatic Weather Stations
SCODS	Standing Committee on Ocean Data Systems (NERC)
SCOR	Scientific Committee on Ocean Research (ICSU)
SCOTSTEP	Special Committee on Solar-Terrestrial Physics (ICSU)
SDB	Synoptic Data Bank
SHAPE	Supreme Headquarters Allied Powers in Europe
SR	Scanning Radiometer
SSU	Stratospheric Sounding Unit
TSO	Time-Sharing Option
TTO	Telecommunication Technical Officer
UK	United Kingdom
UKOOA	United Kingdom Offshore Operators Association
UKWMO	United Kingdom Warning and Monitoring Organization
UNEP	United Nations Environment Program
Unesco	United Nations Educational, Scientific and Cultural Organization
URSI	International Union of Radio Science (ICSU)
USA	United States of America
UWIST	University of Wales Institute of Science and Technology
VDU	Visual Display Unit
VHRR	Very High Resolution Radiometer
VOF	Voluntary Observing Fleet
VS2	Virtual Storage System
VTPR	Vertical Temperature Profile Radiometer
WMC	World Meteorological Centre
WMO	World Meteorological Organization
WWW	World Weather Watch (WMO)

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